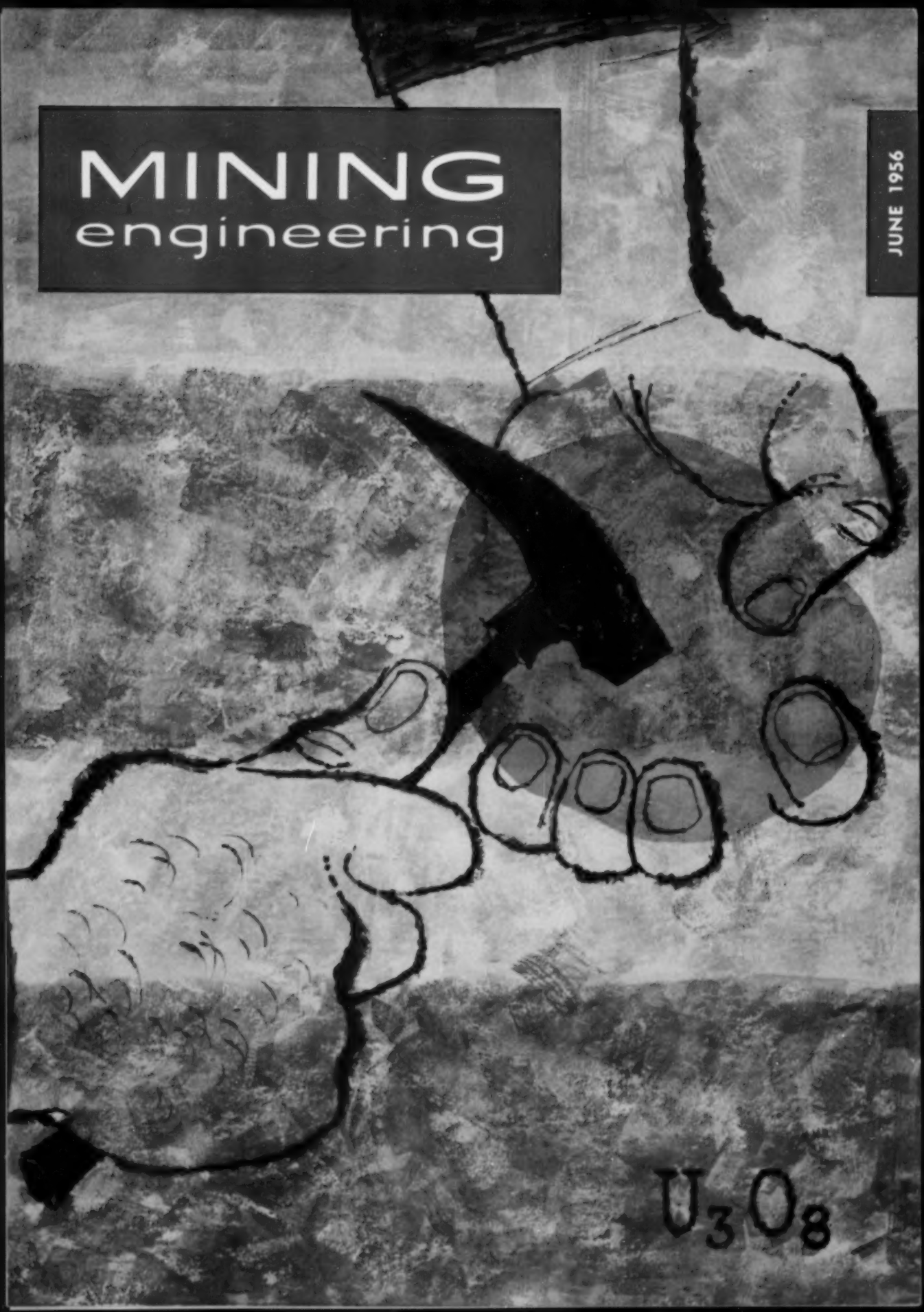
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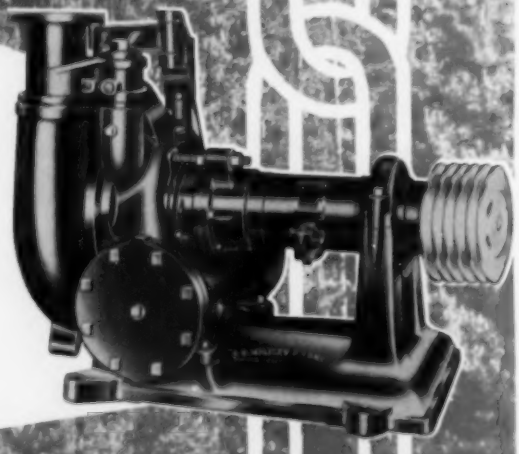

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MINING engineering

VOL. 8 NO. 6 JUNE 1956

COVER

New industries almost invariably mean new material sources. The successful development of a nuclear industry, now underway, is also the story of a successful raw material search, and successful metallurgical development. Artist: Herb McClure.

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Mining Geologist, B.S., 36, married, three children. Twelve years varied experience in exploration and mining geology and engineering. Desires position in mining or geology. M-269.

Mining Engineer, 38, married, three children. Underground mine superintendent; chief metallurgist with pilot plant experience; flotation mill superintendent; construction and operating superintendent for drying plant; 15 months consulting in mining and milling in Spain. Experienced in charging and discharging of ships. B.S., University of Missouri. M-270.

Mining Engineer, Superintendent, 31, married, two children; E.M., Colorado School of Mines. Six years experience with major gold producer in underground production, shaft sinking, mineral-land evaluation, and mill design. Will go abroad. Available June 15. M-271.

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Engineers. (a) Superintendent, mining engineering graduate, with underground production experience in Latin America for tin and tungsten property. Salary, $8,000 to $10,000 a year. (b) Mining Engineer, with underground surveying and general mining experience and knowledge of Spanish. Single applicants preferred. Housing and other extras. Salary, $7000 to $7500 a year. Location, Bolivia. F3202.

Engineers. (a) Mining Engineer, with about ten years underground mining experience. (b) Ore Dressing Engineer, with experience on milling of metal ores. (c) Geologist, for routine operations in metal mine. Knowledge of Spanish desirable. Location, Bolivia. F3130.

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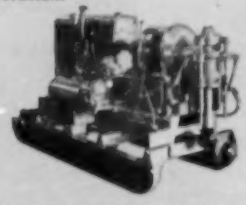

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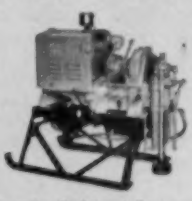

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LETTERS

Gentlemen:

As a geologist who believes in his profession, I have been mildly annoyed by articles in newspapers and popular magazines reporting that amateur prospectors can find more uranium than professional geologists because theye're smart enough to look where the experts know it can't be. But when I read this statement (even though it was attributed to an anonymous AEC "spokesman") on page 264 of March 1956 MINING ENGINEERING, I really blew a gasket.

For 20 years, I've paid dues to AIME because I believe in its avowed purpose (constitution, article 1, section 2): "To promote the arts and sciences connected with the economic production of the useful minerals and metals, and the welfare of those employed in these industries***." Do you really think you're promoting geology and engineering by printing, with no further explanation, a statement which says that geologists don't really know anything about exploring for ore deposits and the layman might just as well trust his own judgment (or lack of it)? Do you really believe this? Would you say it also applied to the search for oil, or copper, or zinc? Would you say that Steen and Joubin were amateurs and that Pick was looking where the experts said it couldn't occur? Uranium, like the other metals, is where it is for good geological, chemical and physical reasons, and the use of scientific methods is just as applicable to the search for uranium as for other types of deposits.

The statement would be more meaningful if accompanied by a breakdown comparing the efforts of amateurs and professionals as to (1) number of tons discovered per man-day, (2) number of tons discovered per dollar spent, and (3) ratio of individuals of each group who have made a significant discovery to the total number involved.

I am also inclined to wonder who these "experts" are who know where uranium can't be found. No geologist of my acquaintance who deserved the title "expert" would express such an opinion. What they do say is that in certain geologic environments it is much less likely to occur than in other favorable environments. This is interpreted by the uninformed prospector as a flat statement that it isn't there. Then when the rare occurrence in the unfavorable environment is found, it is offered as evidence of the geologist's ignorance. I wish there were statistics available to show the tremendous amount of money wasted by amateur "rainbow-chasers" in unintelligent aimless search for the pot of uranium at the rainbow's end.

I am strongly in favor of encouraging laymen to prospect, but let's not delude them by withholding the true odds. Let's encourage them to learn and use geology, not ignore it. And, for everybody's sake let's not low-rate the geologic profession. If our own Institute doesn't believe in us, who can be expected to?

(ED. Note—In a second letter on this subject Mr. Laurence made the following additional comments.)

I was, of course, aware that the objectionable opinion did not originate with AIME, but I felt that, by neglecting to comment on it, AIME indirectly appeared to be supporting it. Also, I hope my letter is not interpreted as an attempt to discredit or discourage the amateurs. I'm well aware of their valuable contributions, but I think they should be encouraged to use all the professional advice and experience they can. Vernon Pick's success is an outstanding example of the intelligent use of professional advice by an amateur.

Robert A. Laurence

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Nuclear Fuels, by David Gurinsky and George J. Dienes, *D. Van Nostrand Co. Inc.*, $7.50, 1956.—Based on much material disclosed for the first time at the Geneva Conference, this volume is divided into three parts: Metallurgy of uranium and thorium; Radiation effects; Solid and fluid fuels. The authors, who are associated with Brookhaven National Laboratory, have prepared this work for scientists and engineers concerned with reactor use or construction, for students and teachers, and for those in industry and finance whose interests are involved in applied atomic science.

Exploration for Nuclear Raw Materials, by Robert D. Nininger, *D. Van Nostrand Co. Inc.*, $7.50, 1956.—The author, AEC assistant director for exploration, has compiled highlights of 130 papers from 26 countries. The methods of prospecting for nuclear metals are developed in logical sequence from nuclear geology to geochemical and geophysical techniques. Included are details of surface, subsurface and aerial radiometric methods with special emphasis on their uses in the U. S., Canada, Brazil and U.S.S.R.

An Encyclopedia of the Chemical Process Industries, by Jeffrey R. Stewart, *Chemical Publishing Co. Inc.*, $12.00, 820 pp., 1956.—Written by the former special assistant to the Quartermaster General, Dept. of Defense, this book treats the practical aspects of raw materials, processes, equipment, and finished products of the chemical process industries. Included are definitions of technical and scientific terms frequently encountered in these industries. As it also lists the manufacturers and uses of thousands of trade-name products, it should serve as a buyers' guide to chemists and consumers.

Legal Problems in Engineering, by Melvin Nord, *John Wiley & Sons Inc.*, $7.50, 391 pp., 1956.—The author, who is an engineer as well as a practicing lawyer, attempts to help engineers avoid legal problems before they arise. Instead of combining law and economics, Dr. Nord emphasizes legal problems and uses cases to illustrate his discussion. By condensing cases and keeping legal jargon to a minimum, the author offers assistance to the nonlawyer, seeking a reliable, concise survey of the field

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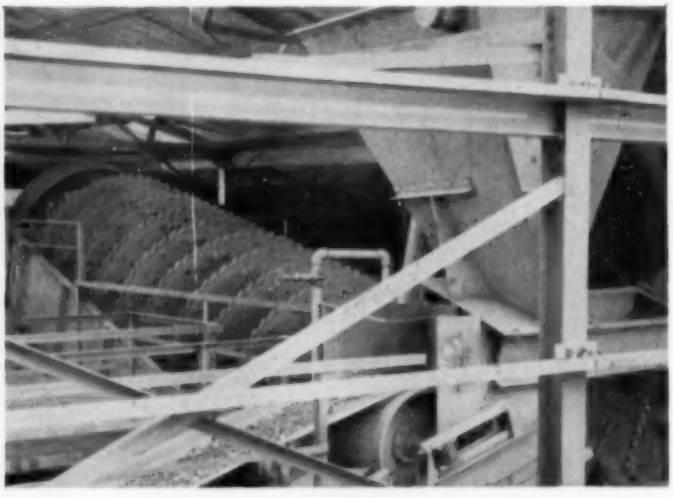

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Simple and safe to store, Akremite can be mixed right at the mine location.

"How We Cut Blasting Costs 50%, Increased Output 20%, with New Akremite Process"

Spencer prilled Ammonium Nitrate is base for new simple, safe, low-cost explosive

"We've found the new Akremite Blasting Process, now in use at our Cheshire, Ohio, operations, to be the ideal explosive for strip mining," reports F. H. Howe, Superintendent of Ohio River Collieries. "Because the ingredients are cheaper and the mixing process so much simpler, we have cut explosive costs 50% with Akremite. At the same time, better fragmentation produced by Akremite lets us move 20% more yards per month.

"The terrain in which we work is unusually difficult, but because Akremite is so safe and easy to handle, we still come out ahead."

☆ ☆ ☆

Akremite, the simple but revolutionary new explosive, is named after its inventor, R. I. Akre, superintendent of drilling at Maumee Collieries Co., Terre Haute, Ind. Akre uses prilled Ammonium Nitrate, produced by Spencer Chemical Company, as the base for his new explosive.

By itself, ammonium nitrate is not an explosive. But Akre found that if he mixed it with carbon black, packed it in a polyethylene bag, confined it in a drill hole and detonated it with a high gelatin dynamite and primacord, it produced a tremendous explosion.

Recently, Southern Research Institute at Birmingham put Akremite through a series of safety tests. They fired bullets into bags of freshly made Akremite. And they conducted the regular pendulum-friction and modified propagation-through-air tests.

Not a single explosion, fire or crackling resulted from any of these tests. Akremite with Spencer prilled Ammonium Nitrate is not only cheaper and better, but many mines report it is the safest strip mine explosive they have ever used.

(NOTE: Spencer Chemical Co. will be happy to provide you with further information about the Akremite Method as discussed by Mr. Howe.)

SPENCER CHEMICAL COMPANY

610 Dwight Building • Kansas City 5, Mo. • BAltimore 1-6600

DART 20S-UG 20-ton end dump shuttle truck. Note driver's swivel seat and dual controls for forward or reverse travel. In reverse, driver sights through porthole in canopy.

OIL from ROCKS VIA 4 DART TRUCKS

For use in its experimental shale oil plant at Rifle, Colorado, the U. S. Bureau of Mines recently put to work four custom-built DART Trucks. The shale mines are underground and the trucks are specially designed to negotiate sharp corners and close quarters. The trucks are driven into the mine backwards and after loading, driven out in forward gear. Then there's a long road-haul to the processing plant. Unusual performance is required. The trucks are powered by 225 HP Diesel engines with Twin-Disc Torque Converters and Fuller 4-speed transmissions. The rock-type body, with removable cab protector, has a capacity of 15 cubic yards.

172,400 pounds of DART Trucks lined up to carry more than 80 tons of oil-bearing shale. With a wheelbase of 126", the trucks turn in a radius of 28'.

Ease of handling the big trucks is a boon to the operators. Hydraulic steering, air brakes and dual controls for shuttling eases the job, adds safety.

Up goes 20 tons! Twin 7½" diameter double acting, two-stage Hydreco hydraulic hoists provide fast and positive dumping.

DART TONNAGE ENGINEERED TRUCKS

Kansas City 8, Missouri

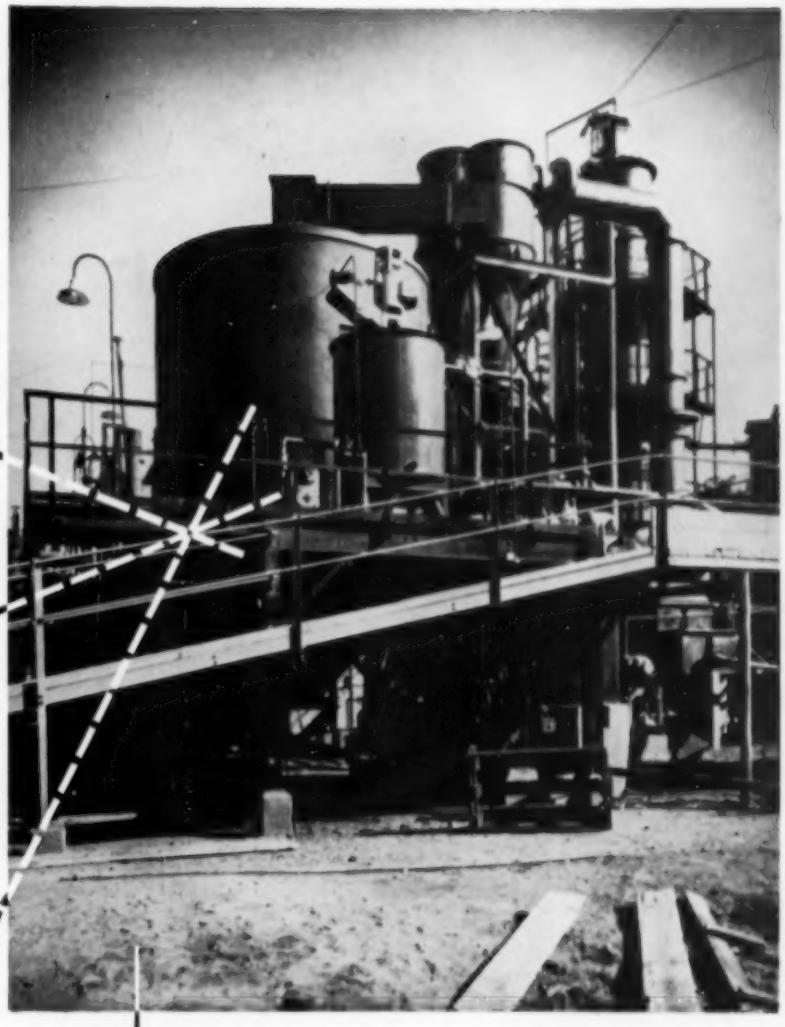
SUBSIDIARY OF THE CARLISLE CORPORATION

D-116

IN SOUTH AFRICA

AROUND THE CLOCK

A TANK CAR AN HOUR OF H_2SO_4



This FluoSolids System at West Rand Consolidated Gold Mines, Ltd. on South Africa's fabulous Witwatersrand was started up early in 1952. The first of several to go into operation on the Rand, it was also the first in the world to combine FluoSolids roasting of pyrite with a contact acid plant.

Over 1650 tons of H_2SO_4 — enough to fill twenty-four tank cars — are being produced every day for uranium leaching at seven South African mills.

An important part of each of these installations is a Dorrco FluoSolids System. Cumulatively the Systems include nineteen Reactors, of which sixteen were on original order and three on repeat orders, plus additional Dorr-Oliver and auxiliary equipment to produce a high strength SO_2 gas for acid manufacture by conventional contact acid plants.

Total feed to the Systems is 1450 tons per day of pyritic gold mill tailings — averaging 35 to 45% total sulfur, gas production is 75,000 to 82,000 SCFM. Gas strength averages 12 to 13% SO_2 . . . sulfur recovery approximately 90%.

The efficiency and economics of the Dorrco FluoSolids System is in evidence in these facts. Additional representative proof that the FluoSolids process can produce an SO_2 gas at lower investment and operating costs than other roasters.

If there's a step in your flowsheet where intimate contact between solids and gases is essential, fluidization should be investigated. Just drop a line to Dorr-Oliver Incorporated, Stamford, Connecticut.

FluoSolids is a Trade Mark of Dorr-Oliver Incorporated, Reg. U. S. Pat. Off.

DORR-OLIVER
INCORPORATED
WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT
STAMFORD • CONNECTICUT • U.S.A.

HOW A NEW IDEA AND A NEW **D8**
CUT MATERIALS-HANDLING COSTS

This new CAT* D8 Tractor is hard at work in one of the sulphur vats in the Texas-Louisiana Gulf Coast Area. Note the special sideboards and extended blade on the No. 8U Bulldozer, which also has back-rip teeth. This rig breaks down vats of sulphur and handles in excess of 400 tons per hour of the light material.

The new D8 handles sulphur more quickly and inexpensively than was possible with the old method of blasting. In addition to saving several hundred cases per month of blasting material and eliminating other expensive related operations, the new Caterpillar D8 Tractor with 'dozer breaks up sulphur lumps and does away with hand picking.

Why was Caterpillar selected? First, because of the close co-operation of the local Caterpillar Dealer in developing this special sulphur-handling 'dozer. Second, because of the excellent performance of other equipment built by Caterpillar, which is used almost exclusively by this producer.

The new Caterpillar D8 Tractor is designed to outwork and outlast any previous crawler. Its new 4-cycle Caterpillar Diesel Engine develops 191 HP. New seven-roller track frame and "water-quench" hardened track shoes give even longer work life. Hydraulically boosted steering, "in-seat" starting and superb visibility give the operator greater efficiency and convenience. The D8 is available with torque converter (Series D) or exclusive oil clutch (Series E) to suit *your* job.

See your Caterpillar Dealer for full details. And count on him for dependable parts and service.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

CATERPILLAR*

*Caterpillar and Cat are Registered Trademarks of Caterpillar Tractor Co.

NAME THE DATE... YOUR DEALER WILL DEMONSTRATE

Manufacturers News

• FILL OUT THE CARD FOR MORE INFORMATION •

High-Flotation Tires

Barrel-shaped, low-pressure Terra-tires by Aviation Products Div. of *Goodyear Tire & Rubber Co.* will take trucks, trailers, and off-the-road vehicles over various types of roadways and terrain. Three to 5-lb inflation, wide load dispersement, and

thin pliable walls are said to allow Terra-Tire equipped vehicles to ride uneven surfaces by conforming with them rather than resisting them. Axle-driven tires are available in wide range of sizes. **Circle No. 1.**

Hydraulic Drill

Mobile Drilling Inc. offers the Model B-40 which operates as a core or auger drill and mounts on the rear of any vehicle. Powered by a 15-hp hydraulic motor, it is used for under-road boring, exploratory jobs, and as an aid in the installation of underground water, gas, and power lines. It is one-man operated and its light weight permits air transportation to remote areas. **Circle No. 2.**

Colloidal Concrete

Laying of grouted concrete is relatively new but is becoming more popular. Aggregate previously placed is covered with grout which has the fluidity of heavy water and fills the voids making a dense concrete. Colcrete colloidal grout mixers by *Chemocem Co.* produce grout without chemical additives and are said to save about 25 pct of cement and sand compared with the usual methods. Labor is claimed reduced as only 40 pct of total material is handled through the mixer. **Circle No. 3.**

Portable Compressor

A 900 cfm size has been added to the Ingersoll-Rand Co. line of Gyro-Flo rotary compressors. Delivering 900 cfm at 100 psi, the unit has capacity to operate 10 jackhammers or 7 wagonjacks with light drifters or 3 wagon drills with heavy drifters. Four other models may be had at capacities of 125, 210, 315, and 600 cfm. **Circle No. 4.**

Smelters

Mace Co. has a complete line of smelters and accessory smelting and refining equipment. Smelting furnace uses diametrically opposed rectangular tuyeres in place of circular tuyeres and they are adjustable for regulating oxygen supply to smelting zone. Air is delivered by a rotary blower with two impellers or a centrifugal turbo-blower. Matting, lead, and combination Mace furnaces are available. **Circle No. 5.**

Color Code for Steel

Joseph T. Ryerson & Son Inc. has a new code to be used on steels produced by the company. Identification system can expand to include new types of steel using the same methods. Single colors are used to identify standard carbon and carbon

manganese steels. Four colors define content and centered dots of these colors indicate heat treated condition. Other colors designate related groups of steels, and red, in any form, indicates special ground finish. Colored pocket size card explains various combinations. **Circle No. 6.**

Impact Mill

The Hy-Ton mill by Crusher Engineering Div. of *Poor & Co.* is designed for high crushing tonnage at low cost per ton. Featured is a hydraulic method of servicing the roller bearings, improved distribution of hammer weight, and overall simplified maintenance. Hy-Ton is claimed capable of production rates up to 700 tph. **Circle No. 7.**

Hydrogen-Sulfide Detectors

One of the more common industrial gases, hydrogen sulfide is known for its distinct odor. But low concentrations may impair the sense of smell for later possibly dangerous collections. *Mine Safety Appliances Co.* has a hand-operated detecting instrument which picks up concentrations as low as 0.0025 pct and up to 0.04 pct by volume. **Circle No. 8.**

Excavator

Model 305 is a ¾-cu yd excavator by *Koehring Co.* that has a rated lift crane capacity of 25 tons on truck chassis, 15 tons on crawler mounting. Upper machinery contains only

two major horizontal shafts. All-welded turntable is equipped with integral sidestands and main cross shafts revolve in antifriction bearings. A full complement of attachments is available. **Circle No. 9.**

Wire Rope Assemblies

Wire Rope Div. of *American Chain & Cable Co. Inc.* has varied combinations of Tru-Loc fittings and assemblies for anchor and conveyor cables, safety belt assemblies, transmission hoists, and other applications which can be suited to special requirements. **Circle No. 10.**

Cutting Material

Made with an aluminum oxide base, Sintox is a tool material by *Sintox Corp. of America* that is claimed to outlast carbide and tungsten tools many times over. Low cost permits discarding rather than regrinding and hardness is calculated between that of a sapphire and diamond. Material is made in one grade which performs at all speeds and feeds. **Circle No. 11.**

Long-Wave Ultra-Violet Lamp

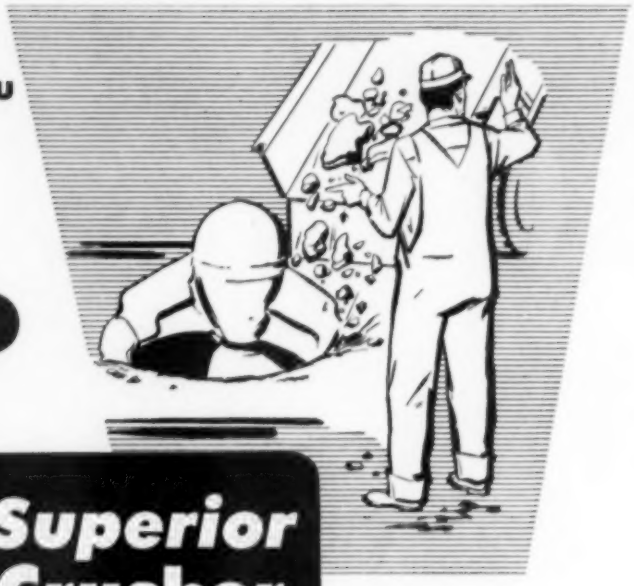
The BLF-6 Blak-Ray is a specialized ultra-violet source intended to identify fluorescence, particularly in the critical areas of pale blue, light green, and red. The lamp, by *Black Light Corp. of America*, utilizes a filter to cut down visible light emission, thereby increasing contrast between the subject and the nonfluorescent background. Long-wave lamp operates on 110-125 v, 50-60 cycle a-c or may be used with a special battery adapter. **Circle No. 12.**

News & Notes

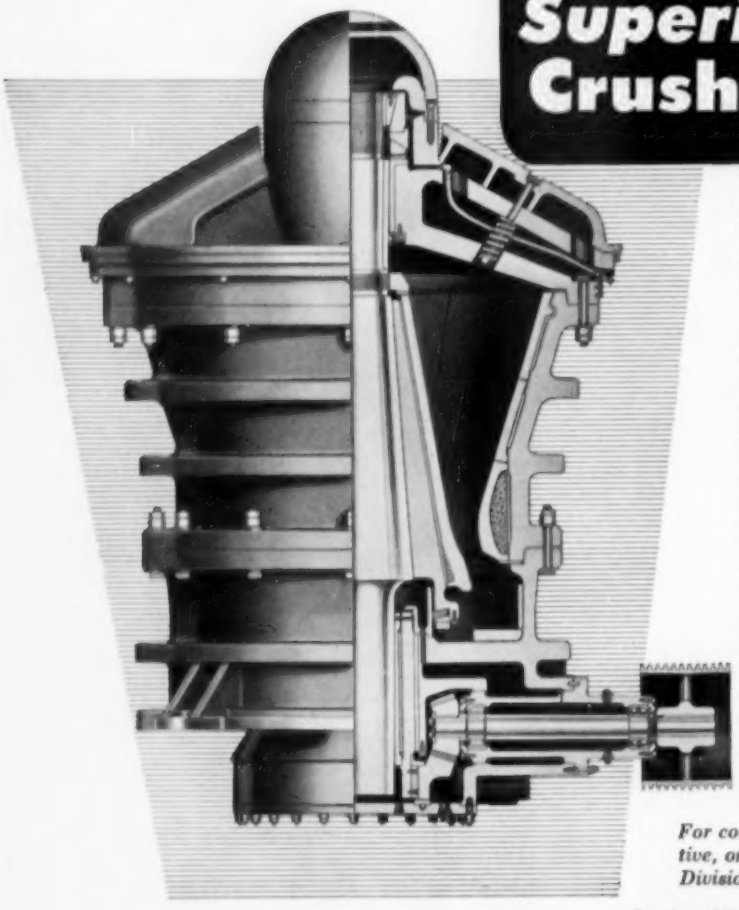
Formation of *Rotary Drilling Equipment Inc.* was recently announced, with offices in Scranton, Pa. The company will manufacture drill rods, stabilizers, and bit adapters and will handle other lines of similar equipment.

Only one crusher gives you

Complete Adaptability for a BALANCED CIRCUIT



Superior Crusher



• With a *Superior* gyratory crusher pacing production, your entire circuit remains in balance. Subsequent equipment—crushers, screens, grinding mills—need not be readjusted to varied product sizes and capacities. The many variable factors provided by the *Superior* crusher permit obtaining the kind of production flow demanded by your other equipment. For example, changing eccentric throws, crusher speed or shape of crushing chamber varies capacity and product size. The *bottom discharge* permits utilizing the concrete foundation as a surge bin to control flow of material through your plant.

Hydroset control is another factor in maintaining a balanced circuit. Retaining the initial crusher setting by compensating for wear is a one-man, one-minute operation when a *Superior* gyratory crusher is so equipped. Emergency unloading is made easier with just the flick of a switch. A-4934

For complete information, see your A-C representative, or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wis., for Bulletin 07B7870.

Superior and Hydroset are Allis-Chalmers trademarks.

ALLIS-CHALMERS

Hammermills | Vibrating Screens | Jaw Crushers | Gyratory Crushers | Grinding Mills | Kilns, Coolers, Dryers

Free Literature

(21) MINERALS & CHEMICALS STORY: *Minerals & Chemicals Corp. of America* offers a 16-page brochure. The "mine-to-finished-product" story of the firm's operations in kaolin, Attapulgite, limestone, and bauxite is told, and notable applications for M&C materials are included.

(22) CIRCUIT RESTORATION: A device for renewing proper electrical conductivity through thermocouples and thermocouple circuits used in heat-treating, melting, and other processing operations is described in catalog R-26 from *Peerless Electric Co.* Diagrams, installation photos, and recorder chart reproductions illustrate the Restorer's monitoring function.

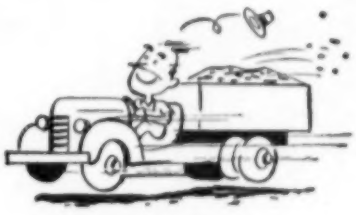
(23) THERMOCOUPLE DATA: Bulletin F-5228-3 by Wheelco Instruments Div. of *Barber-Colman Co.* has 40 pages on construction and application of thermocouples and radiation detectors as used in industrial control applications. Included are standard thermocouple temperature-millivolt equivalents with temperatures expressed on the International Temperature Scale of 1948.

(24) SCREENING: A 4-page illustrated booklet on Wissco-loy Space Screens is available from Wickwire Spencer Steel Div., *Colorado Fuel & Iron Corp.* Knuckles on the screens are clipped to prevent hidden wear at wire intersections. Recommended applications and suggestions are included with specifications.

(25) DREDGES: *Yuba Consolidated Gold Fields* has a folder offering six dredges now available for sale at highly flexible terms because their ground is worked out. Dredges can be remodelled to meet work needs of any placer deposit where they may be floated. Yuba offers to fit a selected dredge with needed machinery, install jigs for concentrating, put in clay handling equipment, redesign it to stockpile ashore or load shore conveyors.

(26) RADIOACTIVE CHEMICALS: Comprehensive catalog on radioactive chemicals and technical services is offered by *Tracerlab Inc.* The 32-page booklet also has tables on beta emitters, hard gamma emitters, and available isotopes listed according to half-life.

(27) TRUCK TIRE HANDBOOK: Suggestions on maintenance of highway and off-the-road tires are offered in a 64-page illustrated handbook by *B. F. Goodrich Tire & Eqpt. Co.* Tire selection chart and load and inflation tables for



tires in highway, earthmoving, mining, logging, and road grader service are included. Section on tire care gives information on inflation, load analyzing, effect of heat, mechanical irregularities, matching and spacing of duals, rotation, rims, and storage.

(28) CENTRIFUGAL PUMPS: Single-stage DMV-DHV centrifugal pumps by *Ingersoll-Rand Co.* have capacities from 250 to 2400 gpm and are intended for general hydraulic services. Redesigned line is detailed in Form 7248-A. Double mechanical shaft seals and pre-lubricated, sealed ball bearings are featured.

(29) VARIABLE SPEED DRIVES: Booklet 20P50 from *Allis-Chalmers* has 44 pages on the selection of variable speed Texrope drives. Information is included on design features, drive principles, horsepower rating tables for A, B, C, D, and E section belts, speed range table on Vari-Pitch sheaves in combination, and accessory equipment for the Vari-Pitch drive.

(30) INDUSTRIAL WIRE ROPE: Hazard Wire Rope Div. of *American Chain & Cable Co.* has a 24-page booklet giving recommendations on wire rope uses in industry. Diameters, construction, preforming, lay, grade, and core are covered, and charts included provide weight and breaking strength specifications. The bulletin, DH-129D, supersedes an earlier edition. Photographs and drawings of typical wire rope riggings and accessories supplement the brochure.

(31) FASTENING TOOL: Ramset fastening tool, called Duo-Jobmaster, seats a specially constructed fastener into concrete, steel and other hard-to-penetrate materials utilizing power generated by a specially-built cartridge. Two booklets on its use are offered by Ramset Fastening System, *Olin Mathieson Chemical Corp.* First shows plant maintenance uses such as fastening of conduits, surface raceways, sprinkler pipes. Second describes a method of lead lining using the tool and also discusses general applications of lead lining. Tool is claimed to cut fastening time by 20 times compared to ordinary methods.

(32) SHAFT MUCKERS: *Shaft & Development Machines Co.* has the Cryderman shaft mucker. Two levers control seven cylinders that actuate a telescopic boom and control opening and closing of a clamshell or hoe-type bucket. The 6700 lb machine operates with an air consumption of 500 cfm. Telescopic boom delivers positive positioning and pressure at point of digging.

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

6

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after Sept. 15, 1956—if mailed in U. S. or Canada

Please send { More Information ☐ / Price Data ☐ / Free Literature ☐ } on items circled.

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51	52	53	54	55	56	57	58	59	60
61	62	63	64	Students should write direct to manufacturer.					

(33) V-BELTS: Feature of Worthington-Goodyear Steel Cable belts is construction using high tensile airplane type steel cables. *Worthington Corp.* has a bulletin on V-belts available for light machinery and heavy industrial drives. Vee Ply belt is quickly detachable and may be adapted to most V-drive applications where continuous heavy-duty service is needed.

(34) DIAMOND TOOLS: "The Diamond Tool Industry in 1955" is a 12-page pamphlet issued by *Industrial Diamond Information Bureau* in London. Survey deals with scientific and technical advances in all branches of the industry. Sixteen divisions are included with references which are also available.

(35) IRON TREATING: "Heat Treating Ductile Iron" is subject of an 8-page pamphlet from *International Nickel Co.* Commercial processes for developing in ductile iron castings tensile strength from 60,000 to 150,000 psi and elongation as high as 25 pct are outlined. Heat treatments for specific industrial applications are also included.

(36) MOLYBDENUM BORIDES: *Climax Molybdenum Co.* has a 6-page bulletin on "Refractory Molybdenum Borides" which describes applications; chemical, physical, and mechanical properties; and preparation of molybdenum boride compounds. Bulletin points to cutting tools as promising field for molybdenum borides, which are comparable to the hardest carbides in hardness.

(37) COAL EQUIPMENT: Bulletin 855 from *McNally Pittsburg Mfg. Corp.* lists a line of auxiliary coal equipment which includes bearings, takeups, holdbacks, chain, screen plates, pumps, and valves. Specification information on conveyor and drive pulleys, V-belt sheaves, sprockets, gears, shafts, and keys is given and photographs and dimension drawings supplement the detailed listings.

(38) ELECTRIC TOOLS: Silver Line and Speed Tool electric tools by *Thor Power Tool Co.* are detailed in a 44-page catalog. Several of the items illustrated have been introduced only recently. Attachments are listed with technical information on each tool.

(39) EARTH-MOVING MACHINERY: Pocket-size review booklet of earth-moving and construction equipment by *Allis-Chalmers* presents machinery and allied equipment in brief form.

(40) VIBRATING SCREENS: Bulletin 290 on Telsmith Vibrating Screens is offered by *Smith Engineering Works.* Telsmith line includes heavy duty scalpers and two types of finishing screens suitable for scalping, sizing, and finishing sand, gravel, crushed stone and ore.

(41) INSULATION PRODUCTS: "Johns-Manville Insulations" is a 20-page catalog providing information on composition, physical and thermal properties, and sizes of *Johns-Manville* insulating materials for general industrial applications. Materials for the efficient control of temperatures from –400°F to 3000°F are covered.

(42) ROLLER BEARINGS: Eight-page booklet 2658 from *Link-Belt Co.* has details on Series S, adjustable single-row self-aligning roller bearings, Series D, adjustable double-row bearings, and Series M, pre-adjusted double-row self-aligning bearings.

(43) SKID-SHOVEL: International Drott Skid-Shovels are available in three sizes, 1 to 2¼-yd capacity. Main advantages are pry-over-shoe breakout, skid-shoe action, parallelogram raise action, according to booklet CR-407-F from *International Harvester Co.* Brochure also includes attachments: rock fork, bull-angledozer blade, log and pulpwood rack, combination rack, scarifier, grubber blade, and buckets.

(44) ELECTRODE HOLDER: Lightweight arc welding Twecotong AL-300 electrode holder by *Tweco Products Co.* is made of aluminum forgings that reduce weight to about half that of conventional holders made of copper castings. Tips and body insulation are of laminated glass cloth. Cable connection will handle cable sizes from No. 6 through No. 3/0.

(45) TRACTOR-MOUNTED RIPPER: *Caterpillar Tractor Co.* claims more profitable earthmoving with the D8 tractor by the use of the No. 8 ripper. Features are Live Drive hydraulic control, pivoted teeth, high alloy steel shanks, replaceable points. Drawbar may be used when ripper teeth are swung up.

(46) TURBINE MIXER: Bulletin from *Cleveland Mixer Co.* describes new K Series Top Entering Mixer. Two-stage helical gear reduction, flexible agitator shaft coupling, self-aligning thrust bearing, flange mounting are some of the features. Selection and rating tables provide specifications of the six available sizes.

(47) INSULATION BLOCK: Bonded Fiberfrax F-20 ceramic fiber block made by *The Carborundum Co.* for high temperature insulation has greater density than the original F-13 material, resulting in improved compressive strength. Five standard sizes may be had in six thicknesses.

(48) COREBREAKER: Weighing 22 lb, the CB27 by Le Roi Div. of *Westinghouse Air Brake Co.* is an all-forged corebreaker that operates on 80 to 95 psi air pressure. Air-cushioned piston hammer is said to produce a powerful blow with little vibration. One-bolt retainer construction allows easy chisel changes.

(49) CRUSHERS: Standard and short head Symons Cone Crushers are described in new 24-page Bulletin 247 from *Nordberg Mfg. Co.* Stationary and portable plant service arrangements are diagramed and listings give dimensions, horsepower requirement, operating speed, and weight of each model. Tables list the various crushing cavities and feed openings, product sizes, and capacities.

(50) NOISE CONTROL: *Mine Safety Appliances Co.* has introduced an electronic instrument to measure and analyze industrial noise. Noise is reported to have resulted in $2 billion in claims against industry. Called Soundscope, the 20-lb instrument is portable and self-contained in a case 16x7¾x7 in. Measurement range is from 24 to 150 db and the analyzer section filters noise into eight principal octave bands in frequencies from 75 to 19,200 cycles per second. Instrument is expected to be useful in combating occupational loss of hearing.

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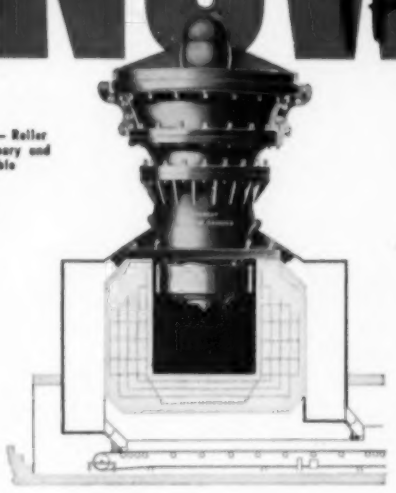
KNOWN THE WORLD OVER!



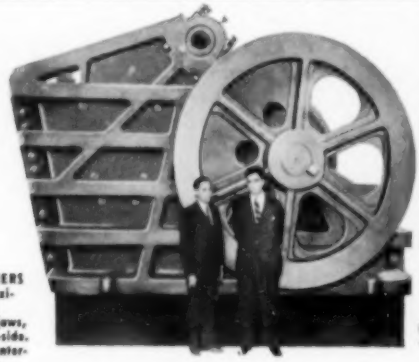
GYRATORY CRUSHERS – Roller Bearing, Gearless, Primary and secondary models. Double discharge outlets, synchronous motor built into pulley assembly or conventional V-belt drive. Power used only for crushing.

KENNEDY • • • CRUSHING AND GRINDING MACHINERY AND EQUIPMENT

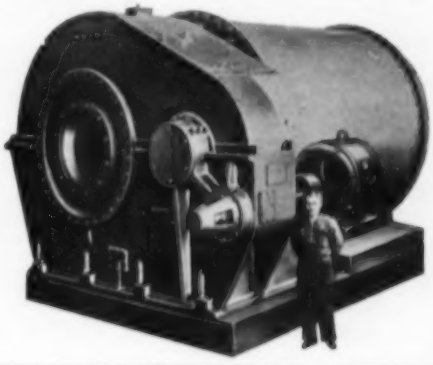
Machinery or equipment designed for crushing, grinding, screening and feeding — noted for dependability and low maintenance cost.

A half-century of experience in manufacturing mining machinery is built into every piece of KVS equipment. From the drafting board through the foundry, machine shop and erecting plant, rigid quality controls characterize our products.

KVS sales-engineers are available for consultation anywhere, anytime.

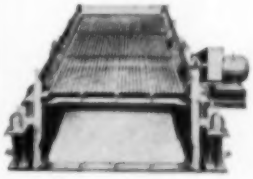


SWING JAW CRUSHERS – Heavy duty, maximum capacity and output. Reversible jaws, end-to-end, side-to-side. Kinetic power, counterbalanced fly wheel.

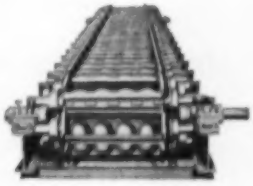


BALL & ROD MILLS — Center peripheral discharge.

AIR SWEPT TUBE MILL – Integral drive, for fine grinding and pulverization



VIBRATING SCREEN – One, two or three decks. Interchangeable mesh, four-way motion. Portable or stationary models.



HEAVY DUTY ROCK FEEDER – Built in any length or width. Overlapping pans for heavy duty service.

WRITE FOR BULLETINS DESCRIBING KVS MACHINERY AND EQUIPMENT

KENNEDY-VAN SAUN

MANUFACTURING & ENGINEERING CORPORATION

TWO PARK AVENUE • NEW YORK 16, N. Y. • FACTORY: DANVILLE, PA.

48,500 Pounds of payload yet this two-trailer hopper train weighs only 29,500 pounds empty.

The big capacity pays off for Motor Freight, Inc. of New Philadelphia, Ohio. This operator uses the equipment to haul coal under contract from mine to a plant 54 miles away.

Deadweight is cut by utilizing USS COR-TEN Steel, a high strength low alloy steel containing nickel, produced by United States Steel Corporation, Pittsburgh, Pa. COR-TEN provides 50% higher effective strength than structural carbon steel. Steels of this type give wide play to the skill of engineers.

62% of gross weight is payload!

Designed to utilize high strength low alloy steel containing nickel

"OUR FUTURE TRUCKS will be of the same material..." declares Robert Ress of Motor Freight, Inc.

Lightweight structures with stamina to withstand impact, battering and abrasion are readily fabricated from high strength low alloy steels containing nickel.

Also, when attacked by atmospheric corrosion, most steels of this type offer 4 to 6 times the resistance of structural carbon steel. As a result, the nickel alloyed steels retain a high degree of original strength over years of use.

Which means much more life per dollar invested.

What's more, use of high strength low alloy nickel steels increases revenue per ton mile. In either of two ways.

1. You can cut deadweight and increase payload without decreasing structural strength.
2. You can increase payload capacity without increasing total weight.

Take advantage of these modern metals. Design your equipment to earn more profit. Moderate in cost, high strength low alloy steels containing nickel along with other alloying elements are produced under a variety of trade names by leading steel companies. Learn more about these steels . . . send for a copy of "Nickel-Copper High Strength Low Alloy Steels." Do it now.

INCO **THE INTERNATIONAL NICKEL COMPANY, INC.** 67 Wall Street New York 5, N.Y.

Sulfur Deposit Discovered on Tehuantepec Isthmus

Stockholders of Texas International Sulphur Co. learned in May that an initial deposit of 5 million tons of sulfur has been uncovered on 300 of the 123,000 acres in the company's concession on the Tehuantepec Isthmus in Mexico. The area, near the Gulf of Mexico port of Vera Cruz, has been the site of significant sulfur discoveries by four other companies.

Domestic and Foreign Copper Operations Expand

Investment authorizations by the Chilean government for expansion of **The Anaconda Co.** and **Kennecott Copper Co.** production facilities are reported to have risen to a new total of $94.6 million since last year when that country passed new legislation favoring increased foreign investment . . . In Arizona, Kennecott's $40 million development program for its **Ray Mines Div.** is expected to yield a 20,000 ton increase in annual production by 1958 . . . **American Metal Co.** reports that the Chibuluma copper and cobalt mine in Northern Rhodesia was recently opened after developing and equipping at a cost of approximately $16.8 million.

Columbium and Tantalum Now Abundant

Vital metals columbium and tantalum are plentiful enough to meet civilian as well as military demands according to the U. S. Bureau of Mines. Less than half of the available concentrates were used last year.

Thorium Operations Planned in Colorado

Preliminary agreement has been reached on the mining and processing of thorium ores by International Minerals & Chemical Corp. and Cotter Corp. of a thorium property near Canon City, Colo.

Small Firm Decline Seen in New AEC Uranium Program

Some smaller uranium mining companies see their business increasingly falling to larger concerns because of the new AEC plan of a post-1962 price guarantee of $8 per lb for U_3O_8. Mill operators will keep ore prices down to increase profits, they say, and only the large mining companies with their own mills will be able to continue mining the ore profitably.

Canadian Activity in Uranium and Asbestos

Amalgamation of Canadian properties of Rio Tinto London and the mining holdings of Joseph H. Hirshhorn has formed The Rio Tinto Mining Co. of Canada Ltd., a uranium holding company . . . Lake Asbestos of Quebec Ltd., a subsidiary of American Smelting & Refining Co. has let a $7.7 million contract to F. H. McGraw of Canada Ltd. for construction of a 5000-tpd asbestos mill.

Gets More

A combination of powerful "pry-out" action using breakout pads as a fulcrum for leverage and a 40° bucket tip-back *at ground level* gets BIGGER LOADS with less spillage.

Keeps More

Heaped loads are cradled closer to the machine for greater stability and can be carried at lower level. Exclusive load shock-absorber cushions the load during travel, smooths out the ride, and permits faster movement with less spillage.

Delivers More

Since you get MORE to begin with and keep MORE while traveling at higher speeds . . . with less spillage in both instances . . . the result — you *deliver* MORE. This new PAYLOADER is a more PRODUCTIVE machine which will handle more yardage at lower cost.

more yardage at lower cost...
New 2¼ yard PAYLOADER®

The new model HO is the finest four-wheel-drive tractor-shovel ever offered. All the *exclusive* features that increase yardage output enable it to handle many kinds of jobs never before practical with wheeled tractor-shovels.

It operates easier and faster, rides smoother, with or without a load, than anything near its size. It has *balanced* design and durability throughout to turn out big production day after day. If you want *proof* of its *productive capacity* and superior *performance,* ask your "PAYLOADER" Distributor for a demonstration.

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More Production, Less Effort

Power-steering, power-brakes on all four wheels, power-shift with no clutching or stopping for range changes and good balance and riding qualities reduce operational fatigue — promote full production all day.

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Pound for pound, the new model HO has more traction and digging power — for a wider range of ground conditions—than any wheeled tractor-shovel ever built.

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SUBSIDIARY—INTERNATIONAL HARVESTER COMPANY

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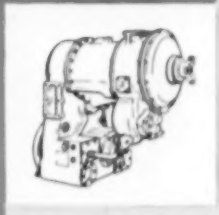
Rugged planetary final drives in the wheel hubs, plus hypoid differential gearing keep torque low in axles, prolong life of drive-train parts as well as axles.



Complete Power-Shift Transmissions

"Complete" since ALL shifts can be made instantly and on-the-go, under full engine speed. There's NO STOPPING for a range-shift, there's no foot clutch pedal. With the forward-reverse control, the operator can "inch" the machine while maintaining full engine speed to provide maximum bucket lifting and dumping power. Torque converter drive cushions power-train shocks.

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EJC Reports on:

Professional Standards and Employment Conditions

"The engineer usually is an employee rather than a private practitioner . . . this creates special problems which are not inherent in the other professions."

"Because the needs, responsibilities, and contributions of professional employees have not been recognized adequately in some instances there has been a movement toward the unionization of engineering personnel."

"The engineer must exercise discretion and judgment, he must wish to serve, and his relationship with management must be one of confidence; in fact he is part of management."

"The engineering employee is bound by the same ethical and moral principles that apply to a member of any other learned profession."

"Management must recognize the inherent professional character of engineering work. It should be a policy of management to use its professional employees to the maximum of their capabilities."

FOREWORD

UNLIKE the members of most learned professions, the engineer usually is an employee rather than a private practitioner. Surveys indicate that about eighty per cent of professional engineers are in the employee classification, and this situation sometimes creates special problems which are not inherent in the other professions. One such problem is how specifically to create and maintain an employment atmosphere consistent with high professional standards.

Certain conditions of employment have had a profound influence on engineers and, among other factors have caused a number of professional employee groups to turn to collective bargaining. There is a need, therefore, for the engineering profession to state clearly the employment conditions that engineers expect as professional men. Employers should align their policies with respect to the engagement of professional engineering personnel to meet these expectations. Mutual understanding between employers of engineers and the engineering profession is essential to the establishment of an environment which will encourage the individual engineer to achieve full professional stature.

A special committee of Engineers Joint Council was charged with a study of this employment problem and the preparation for Engineers Joint Council of "a means of education of and vertical communication to the membership of the constituent societies (including students) concerning conditions surrounding unionization of professional personnel."

Another assignment of the special committee was the preparation of information for employers of engineers concerning employment practices, educational opportunities, and general measures for professional development that influence the attitudes of engineers toward a true professional outlook.

This study treats but one of many problems confronting the profession. Engineers Joint Council will continue its study of the problems related to the employed engineer.

(The full text of the EJC Report "Professional Standards and Employment Conditions" appears on this page and on pages 590, 595, and 607.

THE PRESENT SITUATION

The expansion of engineering from its beginning in military and civil engineering a century ago to a multiplicity of disciplines today has created a host of problems. Of major concern to the engineer is his relationship as a professional man with his employer. This relationship is influenced largely by employment conditions including salaries, training programs, security policies, levels of responsibility, job classifications, and identification with management.

Because the needs, responsibilities, and contributions of professional employees have not been recognized adequately in some instances there has been a movement toward the unionization of engineering personnel. This has had an adverse affect on the professional concepts of many engineers, for a professional man must rely first on his own personal competence and integrity for recognition. In addition, confidential relationships which should exist between employers and professional engineers have been jeopardized.

The fact that there has been a trend toward collective bargaining by engineers, in spite of widespread reluctance to participate in such action, indicates the existence of unsatisfactory conditions. The engineering profession and management have a great stake in the solution of the problem and the latter must accept its share of the responsibility for alleviating unfavorable employment conditions.

THE CAUSES OF THIS CONDITION

Reasons which have fostered collective bargaining among engineers have been studied and may be grouped as follows:

Professional Treatment

1. A feeling among engineers that they were not identified with management, whether they were employees in industry, private engineering firms, or public service.
2. Inadequate channels of communication between top management and nonsupervisory engineers.
3. Inadequate recognition of the engineer as a professional employee.
4. Assignment of engineers to subprofessional work.
5. Undue retention of engineers in specialized and narrowly compartmentalized assignments.
6. Lack of appropriate means for resolving individual problems.

Personal Treatment

1. Inadequate recognition and treatment of the engineer as an individual.
2. Lack of broad position classifications and appropriate titles by which the engineer could measure his progress.
3. Inadequate or nonexistent plans for training and job rotation.
4. Inadequate understanding of promotional policies and belief that progress and promotions were not commensurate with ability and performance.
5. Feeling of insecurity of employment.
6. Management's human relations knowledge and skills have not kept pace with the expanded utilization of engineers.

Financial Treatment

1. Engineering salaries not commensurate with fundamental contribution.
2. Too small a differential between the pay of engineers and members of the skilled trades.
3. Salaries of experienced engineers not sufficiently increased, in comparison with present starting salaries.
4. Wide variation in salaries paid to engineers doing comparable work in different organizations.
5. Dissatisfaction with merit review systems and inadequate understanding of salary administration.

Faced with these conditions, some engineers have resorted to unionization in the belief that corrective action could be effected only by pressures on management through collective bargaining. Even though they may have realized that professionalism requires freedom of action, these engineers appear to have been willing to submerge this principle in their attempt to get more pay and better working conditions through union activity.

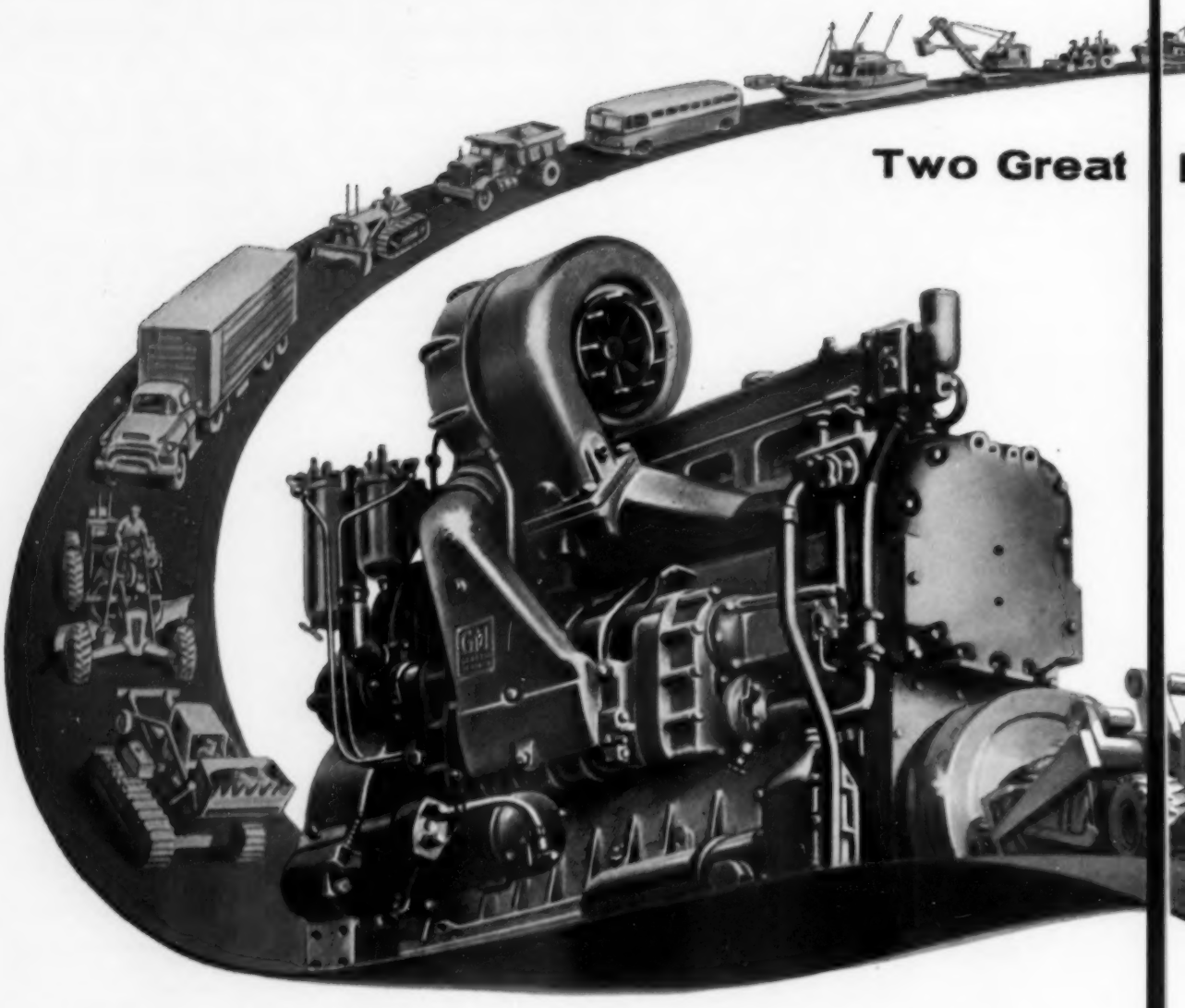
SUMMARY OF HISTORICAL BACKGROUND

The accelerated development of mass-production techniques in this century stimulated a rapid rise in labor union activities. Labor and management faced common problems of increasing complexity. In 1935 the United States Congress enacted the National Labor Relations Act, better known as the Wagner Act, which guaranteed to employees the right to organize and to bargain collectively and protected labor unions against specified unfair labor practices on the part of management. At that time there was little realization on the part of the professions of the potential impact of the Wagner Act on professional employees. However, the established labor unions soon took advantage of the situation and it was not long until many professional employees found themselves included, against their individual desires, in heterogeneous bargaining groups.

Legally, it was possible to form bargaining groups composed solely of professional employees. Practically, it was difficult to do so. Wherever a heterogeneous bargaining unit existed, it was next to impossible for professional employees to segregate themselves since the Wagner Act made no distinction between them and nonprofessional workers.

Some engineering societies, particularly the American Society of Civil Engineers, undertook to chart a course of action designed to assist professional employees against inclusion in heterogeneous groups. At first, the effort met with but minor success. Later, Engineers Joint Council determined to present its views to Congress with the hope that the Wagner Act might be amended to provide recognition of the status of professional employees and to enable them to act effectively on their own behalf. Pertinent clauses are included in the Labor Management Act enacted by Congress in 1947—better known as the Taft-Hartley Act.

(Continued on page 590)



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Turbopower Diesels are additions to Detroit Diesel's time-proved Series 71 line, world's most widely used Diesel engines. The four-cylinder Turbopower Diesel delivers 171 H.P. at 2300 R.P.M.; the six-cylinder engine produces 280 H.P. at 2300 R.P.M.

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EJC REPORTS— Continued from page 587

Of interest to the engineering profession, this law specifically provides under Section 9 (b):

> "The Board shall decide in each case whether, in order to assure to employees the fullest freedom in exercising the rights guaranteed by this Act, the unit appropriate for the purposes of collective bargaining shall be the employer unit, craft unit, plant unit, or subdivision thereof; PROVIDED that the Board shall not (1) decide that any unit is appropriate for such purposes if such unit includes both professional employees and employees who are not professional employees unless a majority of such professional employees vote for inclusion in such unit . . ."
> The term *professional employee* as included in the Act reads
> "(a) any employee engaged in work (i) predominantly intellectual and varied in character as opposed to routine mental, manual, mechanical, or physical work; (ii) involving the consistent exercise of discretion and judgment in its performance; (iii) of such a character that the output produced or the result accomplished cannot be standardized in relation to a given period of time; (iv) requiring knowledge of an advanced type in a field of science or learning customarily acquired by a prolonged course of specialized intellectual instruction and study in an institution of higher learning or a hospital, as distinguished from a general academic education or from an apprenticeship or from training in the performance of routine mental, manual, or physical processes; or, (b) any employee who has (i) completed the courses of specialized intellectual instruction and study described in clause (iv) of paragraph (a), and (ii) is performing related work under the supervision of a professional person to qualify himself to become a professional employee as defined in paragraph (a)."

Under the Taft-Hartley Act a group of professional employees in any place of employment may decide by majority vote of their own numbers whether they want to form a unit of their own for collective bargaining purposes, to join with some other bargaining group, or to refrain from collective bargaining entirely.

It was hoped that the amended act would provide a satisfactory solution to the inclusion of engineers in heterogeneous unions. Professional employees could disassociate themselves from heterogeneous groups. It was not expected that employees of professional status ever would desire anything like a nation-wide bargaining union. It was hoped that labor unions would respect the statutory rights of professional employees.

Those hopes today lack much of full realization.

A number of bargaining groups of professional employees have come into existence. Some appear to have functioned constructively; the same hardly can be said of others. Already there is a nation-wide union, self-designated as an engineering union, which aspires to power. Although some professional employees have been able to disassociate themselves from heterogeneous groups, craft unions, particularly in the construction industry, are forcing more and more engineers into their ranks by bringing economic pressure upon employees, thus avoiding the election machinery of the Taft-Hartley Act. Clearly, many members of the engineering profession and employers of engineers are not doing enough to ensure enforcement of the letter and the spirit of the law.

The recent merging of the American Federation of Labor (AFL) and the Congress of Industrial Organizations (CIO) brings into being a large and powerful labor organization among whose objectives are increased efforts toward unionization of office employees and technical personnel. That effort will have direct impact on professional engineers.

To obtain reliable statistics regarding the current status and thinking of a cross-section of the engineering profession, four constituent members of EJC, namely, ASCE, ASME, AIEE, and SNAME, polled 117,917 of their members on specific questions concerning collective bargaining. Of those polled 66,938 or 57%, responded.

Returns showed that 48,082, or 72%, of the 66,938 respondents opposed collective bargaining for professional engineers, and that 44,168, or 66%, felt that collective bargaining is incompatible with professional status.

Further, the 66,938 responses showed that less than 4% were actually members of established collective bargaining groups; 27% reported as not being opposed to collective bargaining; 20% reported that they believed collective bargaining would be advantageous to them; and finally, less than 1% of the membership of three member societies (the fourth did not ask the question), would prefer to be represented by a craft labor union.

These results present a challenge to the engineering profession and to engineering management. The thinking of the remaining 43% of the 117,917 members polled, who did not respond to the questionnaire, is still unknown, but, assuming that the sample was representative, there would then be 30,300 members who are not opposed to collective bargaining for professional engineers.

These results emphasize the situation confronting the profession in spite of the protective clauses in the Taft-Hartley Act.

Statement of the Problem and Suggested Solutions

A summary of the above might lead to two basic reasons for the present situation:

1. Engineers have not always realized and understood the professional characteristics of their roles.
2. Management has not always realized and accepted its obligations to engineers.

If these are the causes, the problem then may be stated as how to get the engineer to appreciate the professional characteristics of his position and how to get management to realize and accept its obligations to its engineers.

Immediately certain solutions present themselves, and these may be listed under five main headings:

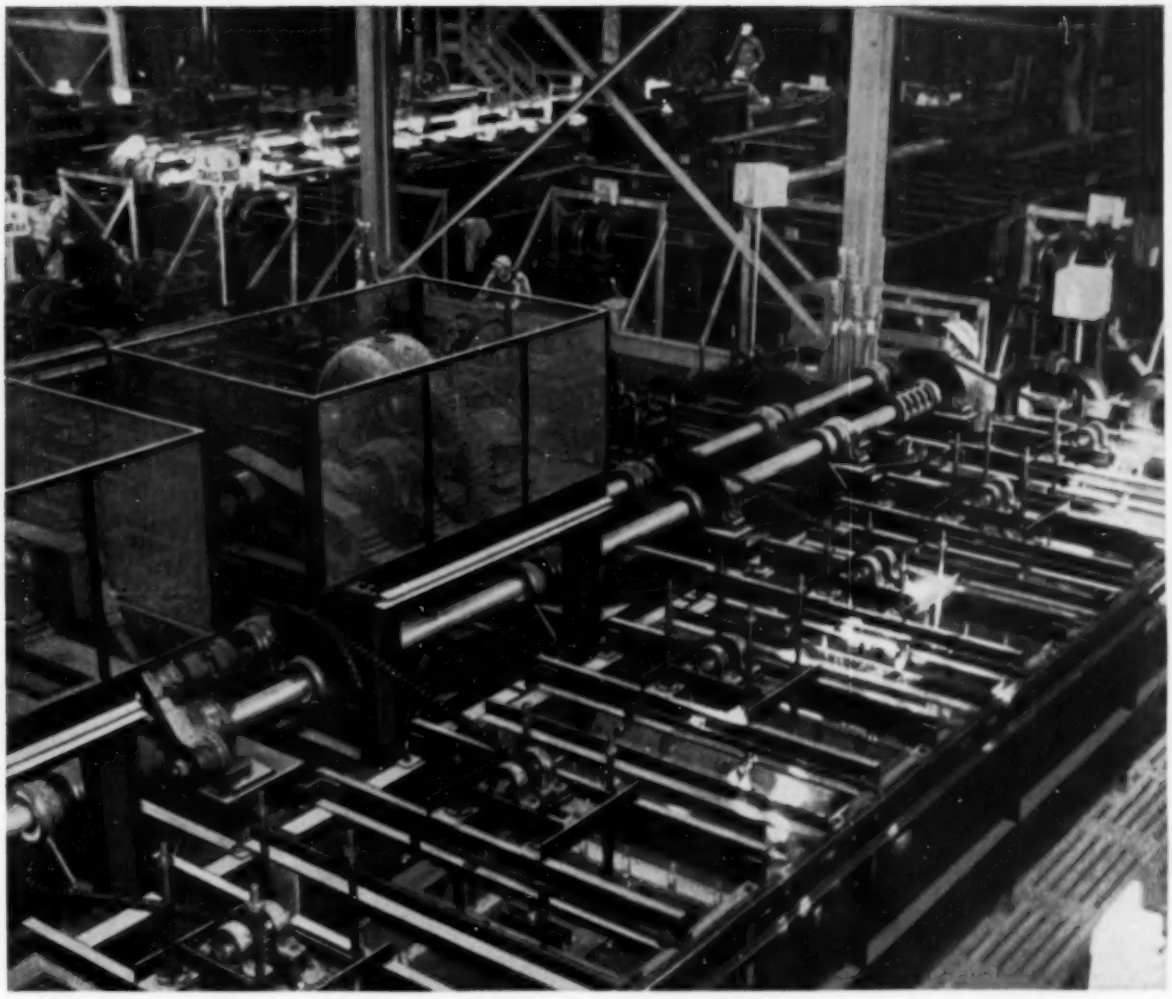
1. Point out to the engineer and reemphasize to him that engineering is a profession and that he therefore has certain definite responsibilities.
2. Point out to management, through all feasible ways, that it has responsibilities to the engineering profession.
3. Point out to professional societies the part which they should play in the advancement of their profession.
4. Point out to engineering educators their responsibilities for developing professional concepts in their students.
5. Point out to society the contribution of the engineer to its general welfare.

The purpose of the rest of this report will be to bring to the attention of all concerned their respective responsibilities. It is hoped that sufficient distribution and publicity will be given to it to stimulate a realization on the part of the public that engineering is a profession with high ideals and one that has made preeminent contributions to our modern civilization and high standard of living.

ENGINEERING—A PROFESSION

Engineering is the art and science by which the properties of matter and energy are made useful to man in structures, machines, and products. Accomplishment of these ends requires not only scientific training, but also creative imagination, judgment, and an appreciation of the economics involved. The work of the engineer is predominantly intellectual and varied. The dictionary defines engineering as a mental activity rather than a manual skill. The engineer must exercise discretion and judgment, he must wish to serve, and his relationship with management must be one of confidence; in fact he is part of management. The engineer is charged with the protection of the public health and the public safety. The builder of a bridge, an airplane, a water supply, a dynamo, a kitchen range, an automobile, or a chemical plant must be concerned with its safe operation. Responsibility rests upon his shoulders; if he does not accept that responsibility, he is not professional.

(Continued on page 595)



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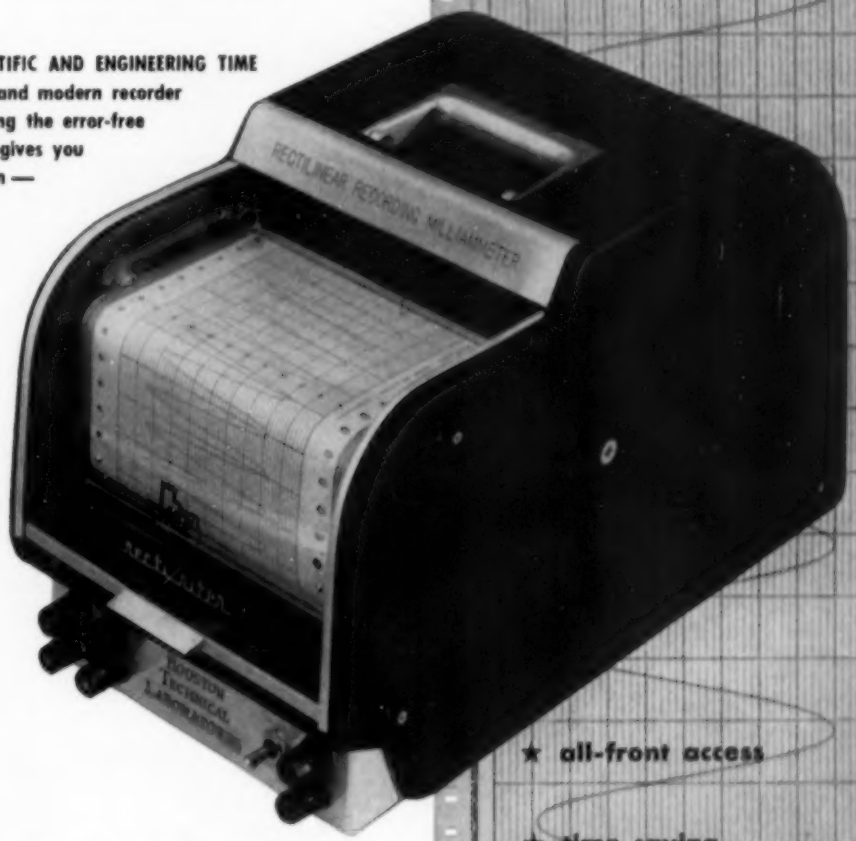

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EJC REPORTS— Continued from page 590

Professions require knowledge and skills on a high plane and all require that the practitioner work in a relation of confidence. In the ministry, medicine, and law this relationship is usually on an intimate personal basis, but in engineering it usually is more general and, indeed, involves obligation to the public at large as well as to the employer or client. The engineer's code of ethics requires that "he will have due regard for the safety of life and health of the public and employees who may be affected by the work for which he is responsible" and that "he will act in professional matters for each client or employer as a faithful agent or trustee."

Since clients and employers usually do not have the technical knowledge necessary to judge technical work, the engineer is bound to place their protection above his personal convenience or his immediate personal gain. A fundamental principle of professional responsibility is trusteeship. This is also a fundamental principle of management. To the employed engineer this means that the professional attitude involves a "management-oriented" point of view.

Engineering operations today are varied and extensive. Men at all levels of training and competence are required to carry out vast engineering enterprises. The work of the draftsman, the layout man, the toolmaker, the plant operator is indispensable, but does not require the imagination, the educational background, nor the judgment of the engineer who conceives and executes the broader aspects of the projects.

The work of a truly professional engineer is so far from a routine, established pattern that only he can provide the initiative, the discretion, and judgment to achieve the successful accomplishment of his particular tasks. Because he alone knows with what comprehension, ability, and likelihood of success he approaches his assignment, the professional must accept individual responsibility or else advise his client or employer that other help is needed.

Professional attitude involves the following five basic concepts:

1. A social consciousness, a desire to contribute *to* rather than simply to benefit *from* civilization; a resolve to place the public welfare above other considerations.
2. The acquisition of special skills on a high intellectual plane, generally evaluated by means of self-imposed standards of excellence.
3. A sense of trusteeship—personal responsibility to protect the client's or employer's interest.
4. Individual initiative and acceptance of individual responsibility, both of the highest order.
5. A right to expect and to receive adequate financial recognition.

Prestige, however, is something that must be won. It cannot be bought or automatically accorded through affiliation with an organization. It is something that one can *command* but never *demand*. In the final analysis, an engineer achieves professional standing only to the extent that he accepts his responsibility to himself, to his client or employer, and to society.

Attainment of a degree in engineering from an institution of recognized standing implies that the graduate has mastered a certain curriculum and that he has the ability to understand, to assimilate, and to apply the knowledge that qualifies him to become a member of the engineering profession.

Although social consciousness is not necessarily a corollary to superior mental competence, most people who are endowed with such competence do have a sense of responsibility to the social order of which they are a part. They have learned to look on life an an opportunity to contribute to the civilization that fostered them and thus to better the lot of those who follow. To the engineer who feels that life provides opportunity for constructive contribution to society, collective bargaining with its attendant potentiality for creating conflicting obligations is not acceptable.

Employee's Responsibilities in the Engineering Profession

"As an engineer, I will participate in none but honest enterprise. To him that has engaged my services as employer or client, I will give the utmost of performance and fidelity." (*Faith of the Engineer.*)

The engineering employee is bound by the same ethical and moral principles that apply to a member of any other learned profession. The responsibilities of an engineering employee are many. He is obliged to perform the professional assignments entrusted to him to the best of his knowledge and ability. He should give needed professional counsel in his special field and render loyal service. He should respect the economic problems of his employer. He should be thorough, expeditious, original, and accurate in the execution of his duties and assignments. He should have a rational attitude toward his work and fulfill each task with a minimum of supervision. At all times he should strive to improve the quality and increase the quantity of his output.

Education is important to the engineer and he should foster its continuance for those who are subordinate to him. He should strive to recognize and to utilize the diverse capacities of all fellow employees. He should strive for good planning and clear, concise reports. He should be friendly and maintain good appearance. He should develop the ability to be a good listener as well as the ability to express his thoughts effectively.

It is axiomatic that just as management has responsibility to employees, so do employees have responsibilities to management. The engineer employee should realize that he is not just another hired hand. He should know that to achieve full professional stature he must develop himself to rise above the technician or engineering-assistant. He must have genuine desire to expand his capacity, to extend his knowledge, and to improve his proficiency.

Any employee who is unwilling to assume responsibilities beyond those accompanying his present job has little right to be critical about lack of advancement. If he feels that he is not getting earned recognition, it well may be that critical self-appraisal is in order. One cannot just wish himself up the ladder or depend on someone else to push or pull him along the way to success. The fact that a man has acquired a bachelor's degree in engineering does not, of itself, entitle him to any lasting professional recognition. It remains for each individual to prove by his own ability, integrity, and conscientious application to duty that he deserves recognition.

Management's Responsibilities in the Engineering Profession

Surveys show that more than forty per cent of management were trained as engineers. It seems illogical, therefore, that often there is inadequate communication between management and engineers with consequent lack of understanding on the part of management of the reasons for dissatisfaction among professional employees.

Management must recognize the inherent professional character of engineering work. It should be a policy of management to use its professional employees to the maximum of their capabilities. Except during the training period the engineer should not be assigned to tasks which do not require his technical training and he should be accorded individual and professional status commensurate with the quality of his contribution.

There must be opportunity for a continuation of education. It is important that professional employees be

(Continued on page 607)

Gardner-Denver . . . Serving the World's Basic Industries

Self-propelled "Air Trac"® drill for rough terrain.

Hydraulic booms and remote-controlled drills for mounting on tractor truck or half-track.

New 5½" heavy-duty rock drill on self-propelled crawler.

All-weather rotaries in 600-foot and 900-foot capacities.

Long-feed tunnel drills and hydraulic booms.

Cost-saving tools for the big push

For open pit production and overburden removal, come to Gardner-Denver for cost-cutting rock drilling equipment. Ask for bulletins.

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THE QUALITY LEADER IN COMPRESSORS, PUMPS, ROCK DRILLS AND AIR TOOLS FOR CONSTRUCTION, MINING, PETROLEUM AND GENERAL INDUSTRY

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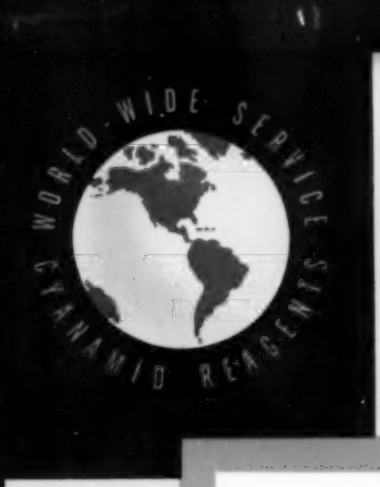
There's a Gardner-Denver distributor in your area—
see him for details



CYANAMID

REAGENT NEWS

"ore-dressing ideas you can use"

AEROFROTH® 65 *Frother Improves Gold Flotation*

This recent report from a Cyanamid Field Engineer tells how AEROFROTH 65 Frother is used to improve overall gold recovery at a Mexican gold-copper operation:

"This plant treats approximately 500 metric tons a day of complex copper ore occurring with gold and pyrite in quartz and calcite. A copper concentrate is produced by flotation with AEROFLOAT® 208 Promoter at 0.1 lb. per ton. Metallic gold is recovered from the copper concentrates, as well as the flotation tailings, through the use of blankets. Before switching to AEROFROTH 65 Frother a combination of cresylic acid and AEROFROTH 70 Frother was used at the rate of 0.5 lb. per ton of ore milled. Present consumption of AEROFROTH 65 Frother is only 0.005 lb. per ton, viz:

Period	Frother	Consumption lb./ton	% Au Recovery
Previous 5-month	cresylic—F70	0.5	72.10
Last month	AEROFROTH 65 Frother	0.005	77.44

"With AEROFROTH 65 Frother in a high-lime circuit at pH 11.2 to 11.5, the gold appears to be more floatable than with other frothers. Since payment for gold in the copper is the same as for gold as bullion, the operators are very pleased with the increased recovery by flotation and the reagent costs".

A Cyanamid Field Engineer will be glad to work with you in your mill to increase recovery through an improved reagent set up. Merely write or phone our nearest office.

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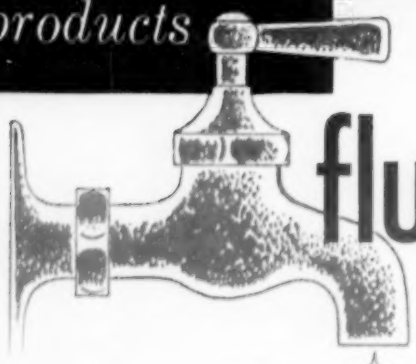
SULPHUR

helps to create headline products



fluoridated WATER

Some communities will, some won't . . . adopt fluoridation of drinking water for the purpose of reducing tooth decay. The subject is hotly debated but one thing is certain: wherever fluoridation is adopted a derivative of Sulphur will enter the picture.

Several chemicals can be used for fluoridation but they all stem from hydrogen fluoride. To produce this gas, a fluoride-bearing mineral is reacted with sulphuric acid.

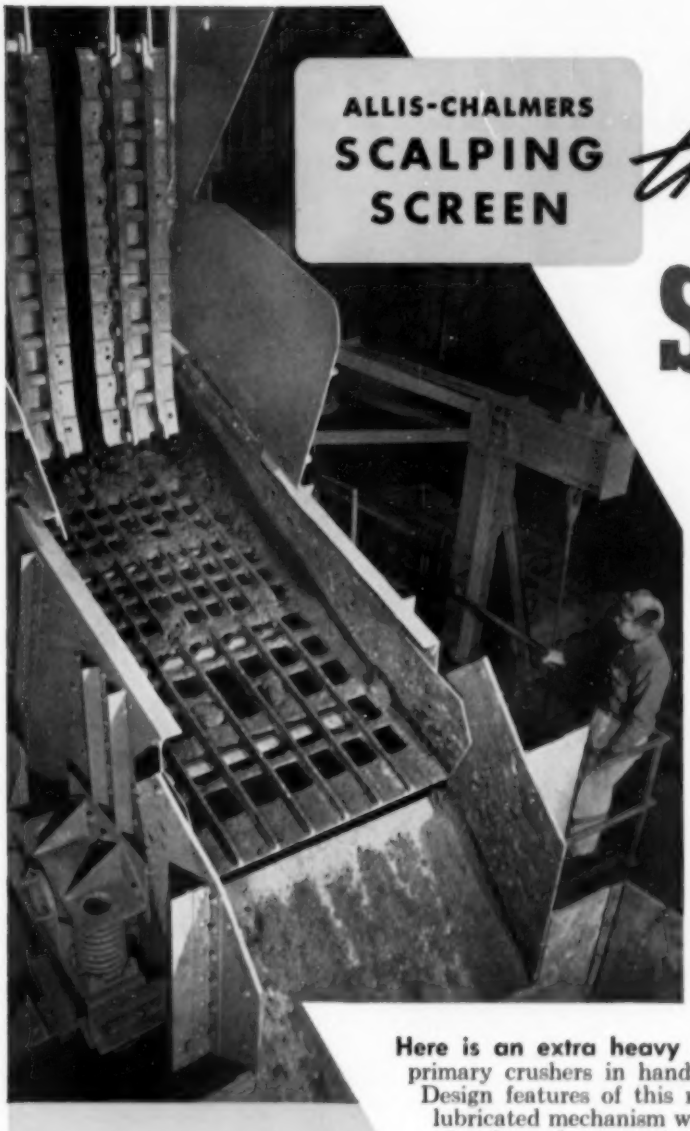
As today's Headline Products' are studied, it's significant that so many require for their production one or more derivatives of Sulphur.

Texas Gulf Sulphur Co.

75 East 45th Street, New York 17, N. Y.

Sulphur Producing Units

- NEWGULF, TEXAS
- SPINDLETOP, TEXAS
- MOSS BLUFF, TEXAS
- WORLAND, WYOMING



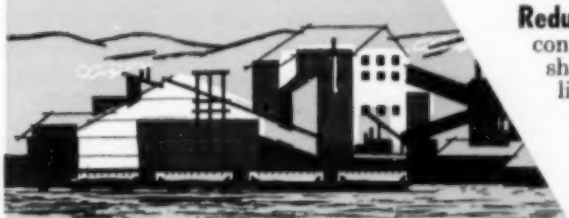
ALLIS-CHALMERS
SCALPING
SCREEN

the BIG SCREEN for the BIG JOBS

- **Extra-Large Mechanism**
- **12-inch I-Beam Deck Support**
- **Takes Punishing Loads**

Here is an extra heavy duty screen engineered to team up with primary crushers in handling the toughest job in any mining flow. Design features of this rugged screen include a cartridge-type, oil-lubricated mechanism with giant size bearings and a 12-inch I-beam in channel-constructed top deck support frame. The bearings, largest ever installed in a vibrating screen, are designed for long term service under heavy load conditions. The sturdy channel construction of the screen deck support frame can withstand the impact of single pieces weighing as much as 8000 pounds.

Performance proved on the *Mesabi* range . . . one of the toughest testing grounds in the world.



Reduced Maintenance — Simplified two-bearing, cartridge-contained mechanism can be pulled out after removing sheave and four bolts. Large size bearings mean extended life, less frequent replacement.

Vibration Isolation — Standard design includes multi-unit vibration isolators — two per corner, each with an inner and outer spring arrangement. Vibration to building or structure is isolated even when materials adhere to screen.

A-5031

For complete information, see your A-C representative or write for Bulletin 07B8368. Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wisconsin.

ALLIS-CHALMERS

HOW TO STOCKPILE 25 TONS

A MINUTE

Pittsburgh & Conneaut Dock Co. stockpiles a million tons of iron ore during the summer months, to create a reserve supply when ore boats cannot satisfy extreme demands. Four CAT* DW21s with Scrapers handle 1500 tons per hour for this Conneaut, Ohio, firm. That means a DW21 pulls away from the Stephens-Adamson conveyor every minute with a 25-ton load.

This company works two eight-hour shifts, six days a week during the navigation season. Its equipment must do a lot of work fast, and stay on the job. That's why a company official says: "We've had 12 years of experience with Caterpillar equipment. We considered other makes, but found DW21s did the job best."

Now there is a new and improved DW21 (Series C) with 300 HP (maximum output) Turbocharged engine. It has 10% greater rimpull and new, wide-section 29.5-29 tubeless tires for maximum traction. With the big-target No. 470 LOWBOWL Scraper (25-yd. heaped capacity), here's an ideal team for efficient materials handling and for earthmoving jobs in slack seasons. For jobs that are exclusively stockpiling, many firms find that DW21s with Athey haulers pay off.

If you want fast cycle times and traditional Caterpillar stamina, investigate the DW21 today. Your Caterpillar Dealer has full details and on-the-job proof that these big yellow rigs can do more work in less time at lower cost on *your* operation. And count on him for skilled service and parts you can trust.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

CATERPILLAR*

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NAME THE DATE... YOUR DEALER WILL DEMONSTRATE

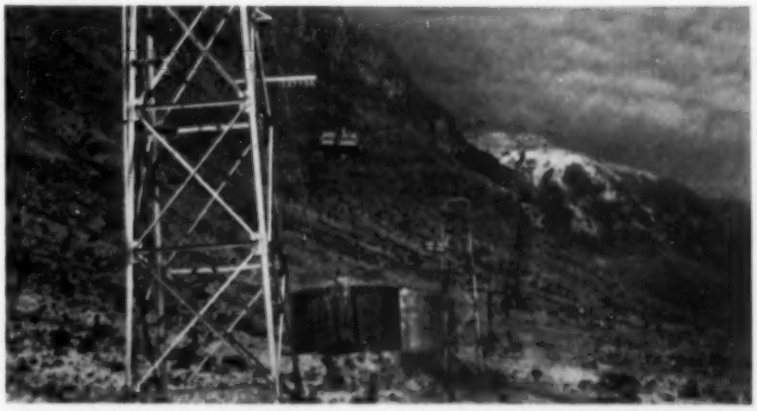
GYPSUM—Mine to Plant

MINING engineering NEWS

Aerial Tramway Speeds Material From Mountain Quarry

A gypsum operation at Blue Diamond, Nev. is successfully using an aerial tramway to bring material from a crusher, down a mountain, to its mill. Blue Diamond Corp.'s quarry is located 1500 ft above the main processing plant and a mile back in the mountains. Trucks haul the gypsum material to a crusher from which it is cable-transported in buckets to stockpiles at the foot of the mountain via the aerial tramway. As needed, a Caterpillar D8 Tractor dozes the material into a hopper that carries it to overhead storage bins. It receives further reducing and is fed to calcining kettles to remove moisture and waste.

At a plant in another building the powdered gypsum is mixed with starch and fiber. This mixture is sandwiched between sheets of paper stock to produce wallboard which is then cut and kiln-dried. Inspection, stockpiling, and shipment complete the routing.



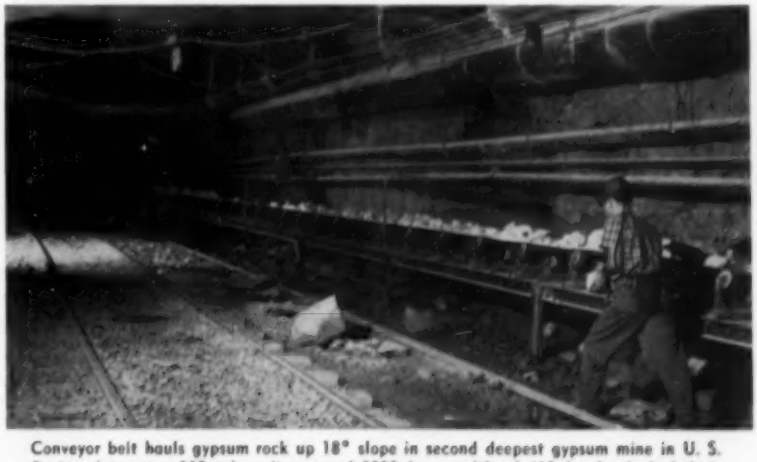
UPPER: Aerial tramway carries gypsum-loaded buckets down from crusher plant (background) which has broken material into 2-in. particles. LOWER: Cat D8 pushes crushed gypsum from stockpile into hopper. Conveyor carries material into plant for waste removal.

Underground Mine Employs Near-Mile Long Conveyor Belt

National Gypsum Co.'s new Shoals, Ind. gypsum mine is the longest underground slope mine in the gypsum industry—2000 ft long and 500 ft deep. Besides a city-like system of roads, shops, offices, locker rooms, power station, and crusher, the mine has the "longest and strongest inclined conveyor belt ever installed to lift gypsum from mine to plant above ground."

Conveyor system was installed by Hewitt-Robins Inc. and uses their Jones speed reducer, allowing the conveyor to be started even while under its 70,000 lb load. Non-metallic, the belt is made of Super Raynile fabric containing rayon and nylon. It stretches to ease the strain of starting the loaded conveyor.

Above ground, the herringbone gear type speed reducer transmits power from a 250 hp electric motor to the conveyor pulley at a reduction ratio of 58.3 to 1, giving a belt speed of 278 fpm. Capacity of the conveyor will eventually be increased to 350 tph from present capacity of 240 tph and a reduction ratio of 47.7 to 1 will then be used. Between 30 and 35 freight car loads of finished gypsum products weighing from 20 to 30 tons per carload roll out of the Shoals, Ind. plant each day.



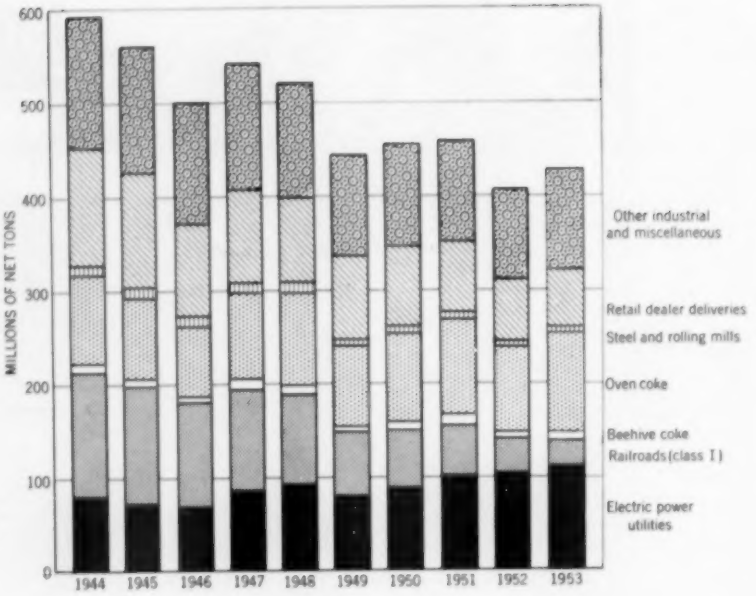
Conveyor belt hauls gypsum rock up 18° slope in second deepest gypsum mine in U. S. Designed to carry 350 tph a distance of 2000 ft up a lift of 610 ft, the 6-ply belt is mildew inhibited and has ¼ in. top cover with cord breaker strip and 1/16 in. bottom cover. Rayon gives it longitudinal strength; and nylon provides cross-wise flexibility and impact resistance.

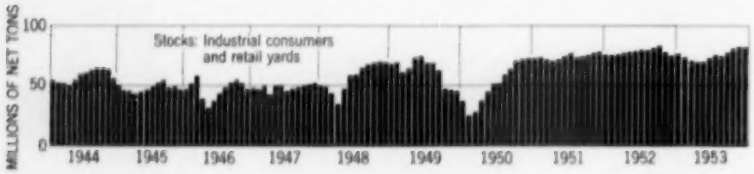
Bituminous Coal Looks to Research

Domestic bituminous coal reserves are large compared with those of other mineral fuels and increasing national energy requirements promise coal producers a greater share in the expanding market—if coal is able to meet increased competition. A recent report by the U. S. Bureau of Mines in cooperation with the industry-supported organization, Bituminous Coal Research Inc. lists over 200 possible areas for research in bituminous coal. Areas range from mining operations to the development of new uses for coal.

Some recommended research projects which might enable the industry to enter competition with greater strength are: nuclear gasification of coal, production of high-heating-value gas from coal, fine coal cleaning, low-temperature coking, handling, and transporting coal underground, intensive mapping of re-

(Continued on page 602)





ABOVE: Consumption of bituminous coal and lignite by consumer class in the U. S., 1944-53. LEFT: Trends of U. S. coal stocks, 1944-53.

EASY OPERATING NON-LUBRICATED

DeZurik

PLUG VALVES

with *Eccentric Action!*

On so many metallurgical service lines, the features found on DeZurik Valves — and only DeZurik Valves — account for their excellent performance records. Their resilient-faced plugs close tight on any line despite solids in the flow; their eccentric action guarantees easy operation, without binding or sticking — without lubrication!

Try a DeZurik Valve on pulp, tailings, slurries, wash water. You'll get tight shut-off, easy operation and low, low maintenance. In sizes ½" thru 20", in a full range of metals and models.

Representatives in all principal cities or write for complete details.

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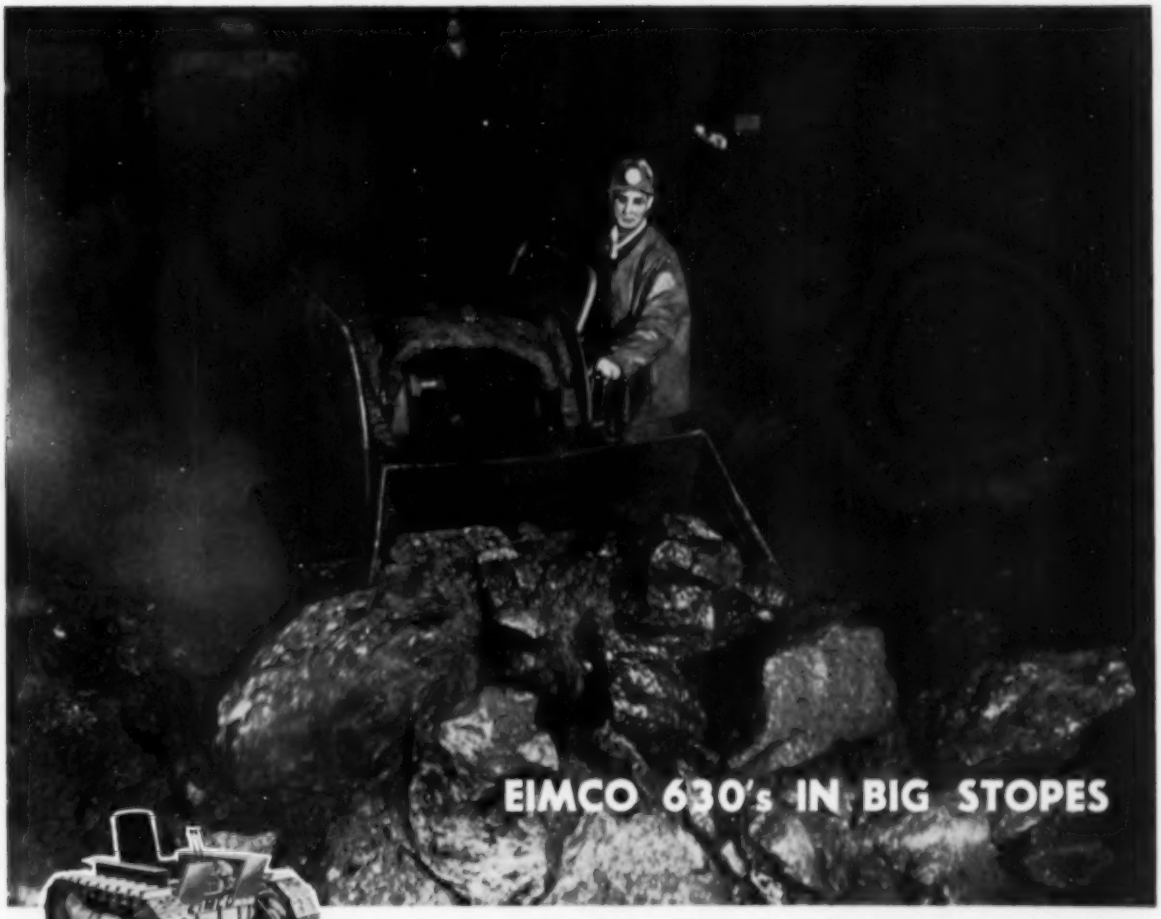
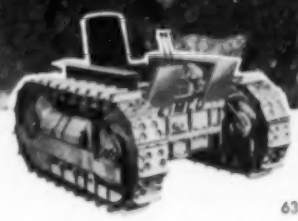
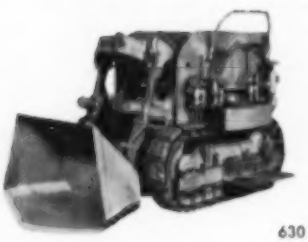


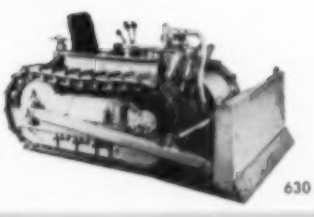
EIMCO 630's IN BIG STOPES



630 Tractor



630 Excavator



630 Bulldozer

Open stope mining has been the proving ground for numerous types of mechanical loading equipment. One type has replaced another as each succeeding piece of equipment has been able to show greater versatility, greater dependability and lower costs.

Mining men in these fields have been quick to try out any equipment, accept it, remodel it or reject it.

Their reaction to the Eimco 630 Excavator has been enthusiastic. "We're re-ordering on the 630, it's giving us the lowest per ton cost and the highest production."

Eimco 630 Excavators have proven their dependability in mines and on contract jobs. Their heavy-duty construction has made them the lowest cost loaders used underground. They are easily controlled, fast in action and their loading speed averages three tons per minute in rock.

Independent track control on the Eimco 630 provides unusual flexibility for the operator. New features built into the 630 provide the ultimate in operator safety, operator convenience and ease in machine care.

The 630 is a rugged, hard working machine with a tough, carefully designed and precision made operating mechanism.

Lower your loading costs with Eimco equipment. Thousands of Eimcos are working every day wherever mining is done. You can depend on an Eimco.

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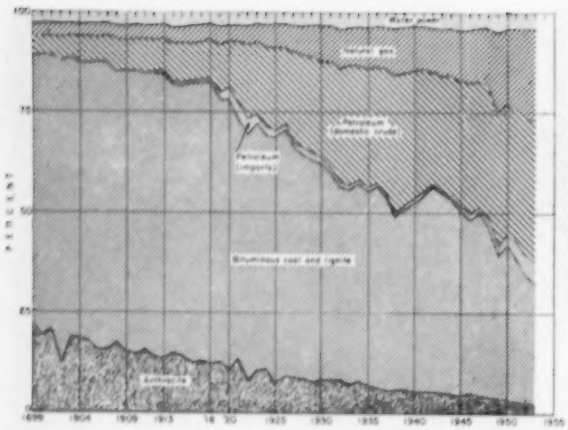
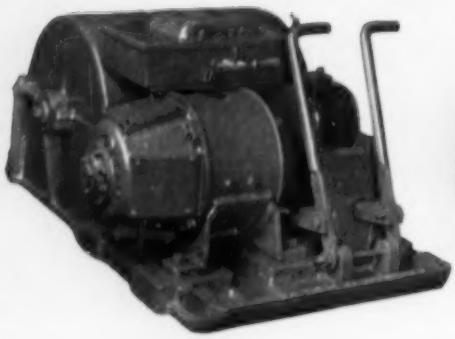


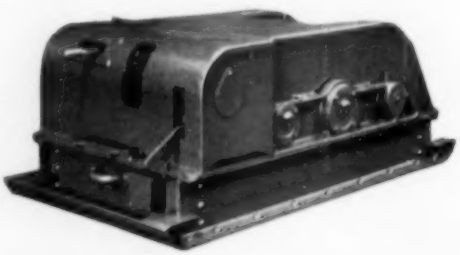
Percentage of total Btu-equivalent contributed by the several sources of energy in the U. S., counting water power at the prevailing fuel equivalent of central stations in each year, 1899-1953.

Headquarters for "BROWNIE" proved mine hoists



IN MINING OF ALL TYPES, there is no haulage hoist problem than cannot be handled by a "BROWNIE". Hoist with a reputation of long standing for dependable service and the ability to take the punching of constant haulage. Let us discuss your problems with you for greater efficiency and more effective service. **Sanford-Day Iron Works, Inc., P. O. Box 1511 . . . Telephone 3-4191, Knoxville, Tenn.**

Among our various types and models available are hoists with rated capacities from 2,000 to 24,000 lbs. rope pull and with speeds from 25 to 300 feet per minute.



SANFORD-DAY

"SUPER MARKET FOR MINE CARS" — *all types* * PRECISION WHEELS * "BROWNIE" HOISTS, CAR RETARDERS, SPOTTERS, PUMPS AND OIL SPRAY SYSTEMS * GISMO SELF-LOADING TRANSPORT *that loads (mucks)* in development or production . . . transports . . . supports 2 to 5 jib mounted drills . . . back fills . . . moves boulder rocks . . . makes its own roadways and cleans up completely — a new method of hard rock mining offering a tremendous reduction in cost per ton!

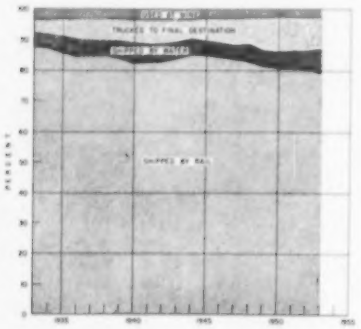
Coal Research

(Continued from page 600)

serves, hydraulic transportation, and basic research on the structure and properties of coal.

The joint study was made to find methods of keeping the domestic coal industry strong while improving conservation, health and safety in mining, processing, and utilization of coal. It surveyed coal research last year in the U. S. and several foreign countries, and included investigations to determine which research projects might be of value to the industry.

According to the report, the amount of money spent in the U. S. for research on coal is small when compared with research expenditures in other industries. Slightly more than $17 million was spent on coal studies in 1955, and much of it went for development and improvement of equipment, the report comments.

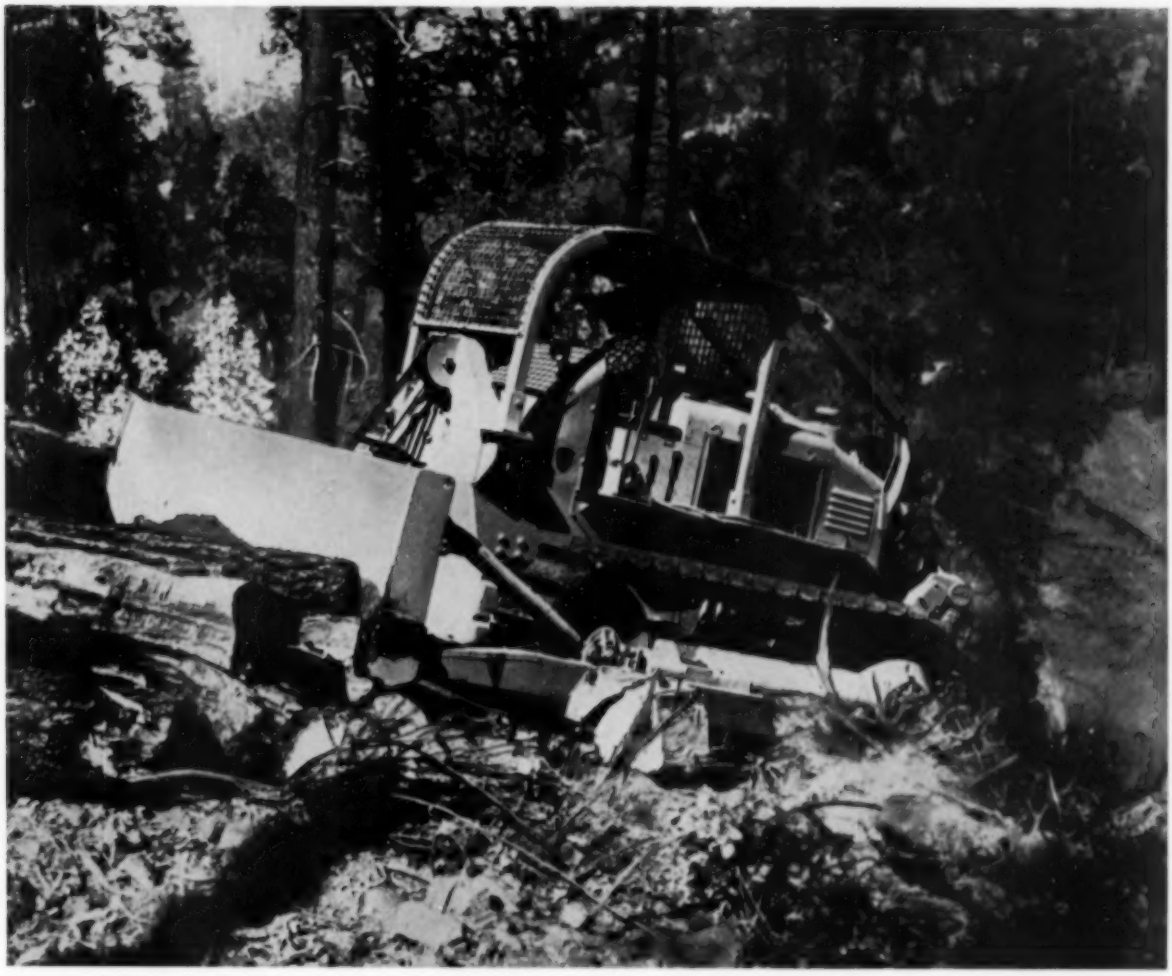


Percentage of total production of bituminous coal and lignite, 1933-53, by method of shipment from mine, and used at mine.

In contrast, the report cites recent annual research expenditures ranging from $28 million for textiles to nearly $146 million by the petroleum industry and more than $360 million by the chemical industry.

Of the total spent for scientific studies on bituminous coal last year, the report says, nearly $5 million came from the federal government, over $3 million from manufacturers of mining and processing equipment, and slightly more than $3½ million from coal-mining companies. The remaining $5½ million was spent by related industries, state governments, universities, and private research organizations.

The report states that "the amount of the energy market that coal will get will be determined by the aggressiveness of the coal industry to obtain these markets." It says further that while many of the research possibilities indicated are similar to previous studies, the amount of time, effort, and money spent on certain problems was insufficient. On the other hand, modern methods have created some entirely new research objectives.



COMPETITIVE TESTS SHOW EIMCO ADVANTAGES

Recent competitive tests have shown again the superiority of Eimco equipment.

Tests conducted in timber and foothill brush were made to determine dozer earth moving and fire line construction ability.

Over a five day period numerous runs were made by impartial crews and judges with experienced operators using an Eimco 105 and a conventional tractor both equipped with bulldozers.

When final results were computed, the Eimco rated "Best" with 33% more dozer earth moving and 11% more fire line construction and the Eimco had also earned operator confidence because it was more stable, easier to operate and would back up 30% steeper grade (the usual method of getting out of trouble).

The features on the Eimco that contributed to its success in the test and outstanding performance under most difficult conditions were: front operator position, better visibility, rear engine mounting, better weight distribution, torque converter, better location and protection of cooling system, better maneuverability (through independent track control) simple controls which eliminate clutch pedals, steering clutch levers, master clutch and manual gear shift lever.

Eimco tractors with bulldozer or excavator attachments are demonstrating their superiority of performance and economy of operation on highways, construction jobs, in mines and in numerous other applications. See the Eimco Tractor before you make any decision on new equipment.

THE EIMCO CORPORATION

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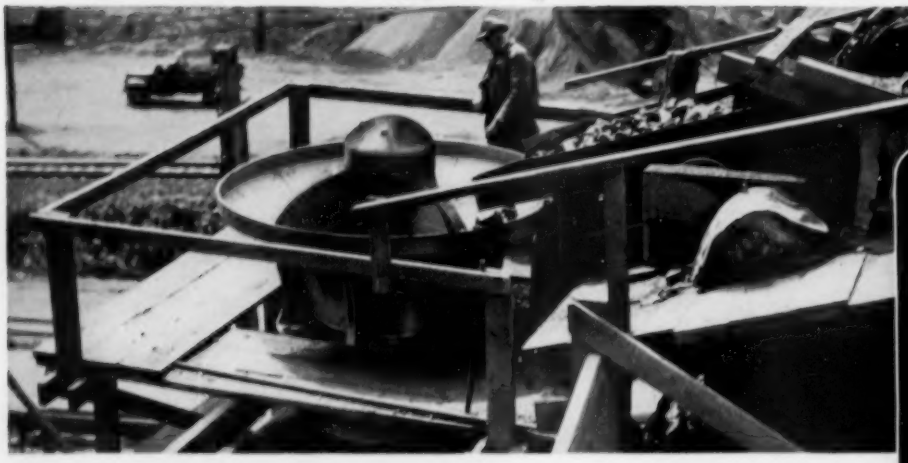
B-202

For Top Tonnage at



Cast steel frame, upper shell and spider in one piece.

Traylor-original, self-tightening bell heads and curved concaves of manganese steel.

Traylor patented dust seal, excludes dust and grit from the lubricating chamber.

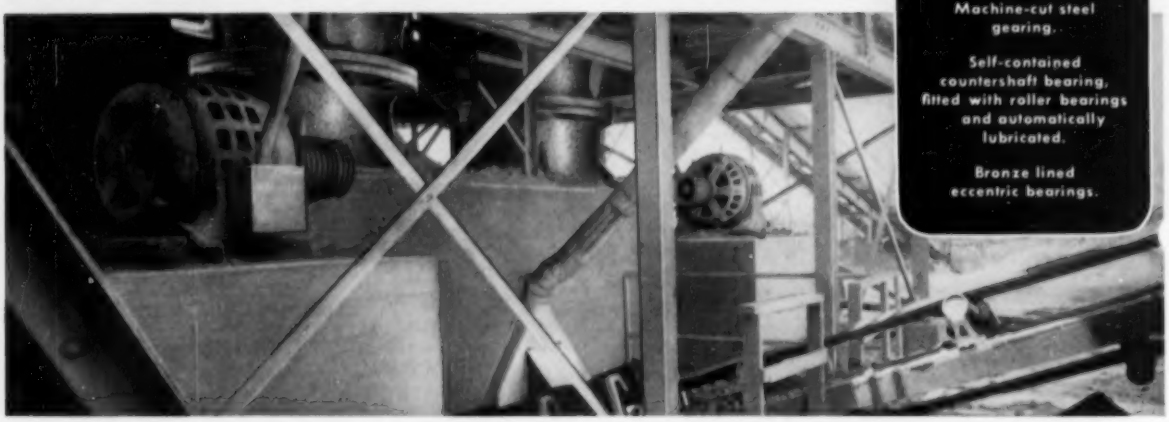
Closed circuit automatic force-feed lubricating system, with filter and oil cooler.

Machine-cut steel gearing.

Self-contained countershaft bearing, fitted with roller bearings and automatically lubricated.

Bronze lined eccentric bearings.

Rock-Bottom Cost



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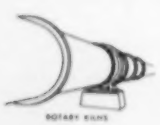
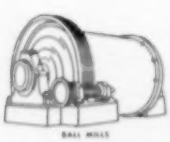


ROTARY KILNS

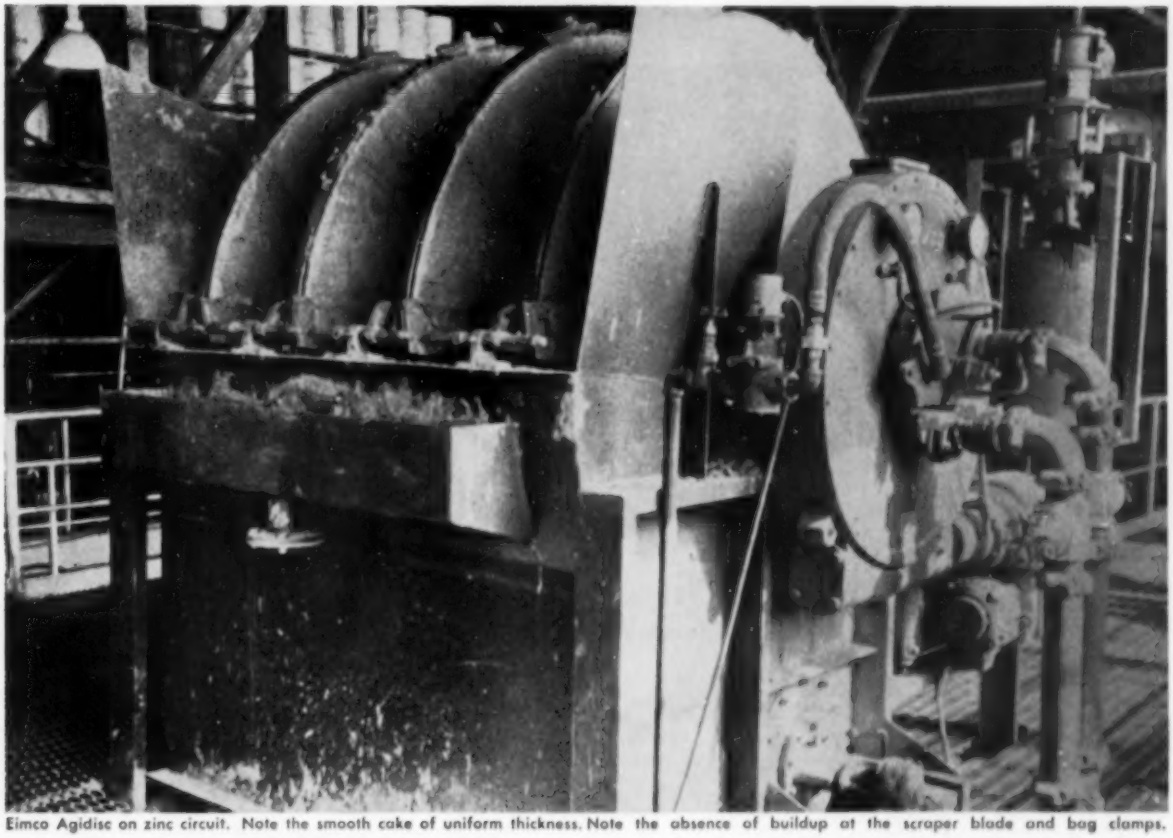
SECONDARY GYRATORY CRUSHERS



BALL MILLS

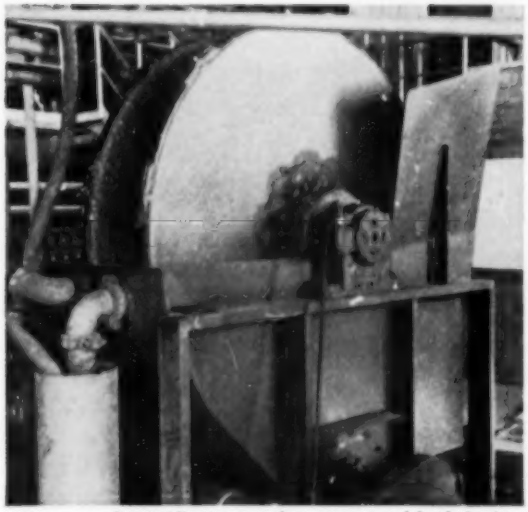
JAW CRUSHERS

APRON FEEDERS



Eimco Agidisc on zinc circuit. Note the smooth cake of uniform thickness. Note the absence of buildup at the scraper blade and bag clamps.

LOW MOISTURE AT HIGH ALTITUDES WITH EIMCO AGIDISC FILTERS



Eimco two disc Agidisc type used on copper and lead circuits.

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MODERN HEAVY-DUTY POWER

given opportunities to participate in activities of scientific and technical societies. It is important that they receive credit for their contributions to the advancement of technical knowledge or the profession as a whole.

There must be adequate communication between management and the professional employee. There should be organized orientation and training programs for new employees. Engineers need to understand the basic policies of their employer. They need to know their responsibilities and their opportunities for advancement. Adequate management-employee communications require a day-to-day relationship supplemented by periodic performance reviews, and other appropriate techniques.

Salaries must be established which will recognize the contribution of the professional employees as related to that of other groups. Salary differentials between various levels of technical experience have been substantially narrowed during recent years. Engineers who, after a period of satisfactory employment, find their salaries are only slightly higher than those of the recent graduate and possibly lower than those of a skilled craftsman are not working in a favorable atmosphere.

Management must minimize the fear of job insecurity by adopting feasible means for stabilizing the employment of professional personnel and suitable termination policies. Since many engineers become managers, there is a need to insure that they are employed and developed in an atmosphere which will fit them for their future responsibilities. Executive talents must be developed by experience and training in those phases which lead to managerial responsibilities.

Engineering Societies' Responsibilities in the Engineering Profession

The engineering societies must take the lead in the advancement of the profession. Among the basic responsibilities of the engineering societies are the establishment of standards of ethical conduct, rigid requirements for admission to membership, accreditation of educational institutions which grant engineering degrees, and awards and prizes in recognition of worthy contributions to the advancement of the profession.

The national engineering societies have an additional responsibility to foster a healthy professional climate for employed engineers. Their governing boards and their individual members should unite in exerting their best efforts toward solving the problem. These responsibilities are so challenging and so vital to the current problem that they must be considered as obligations.

Current efforts of national committees to encourage professional development of engineering society members and to promote recognition by the public of the professional character of the engineers' work should be expanded. An objective evaluation of the problem should be continued, followed by specific recommendations for the good of the profession. Engineering societies should adopt official statements for membership information with respect to collective bargaining to the extent permitted by their charters and constitutions. They should acquaint their memberships with those provisions of the Taft-Hartley Act which have a special significance to professional engineers. Constructive programs for encouraging professional consciousness on the part of engineers both before and after graduation should be sponsored. Therefore, the engineering societies and Engineers Joint Council should inform management as to the standards that will contribute to full professional achievement.

The engineering societies should provide guidance and assistance to educational institutions confronted with any problem which is detrimental to the achievement of full professional training of students.

Engineering Education's Responsibilities in the Engineering Profession

Engineering colleges have a primary responsibility for developing professional concepts in engineering students. Professional concepts should be developed through their application to the solution of engineering problems in the technical courses, lectures, association with students, and by good example.

Opportunities for engineering educators to become better acquainted with the total environment in which engineers work should be expanded through temporary employment in nonacademic fields and the utilization of employers with "professional vision" in the classrooms and student seminars. Such activities enable students to appraise their status more realistically upon graduation.

Conclusions and Recommendations

There are obligations and responsibilities resting on both employer and employee. Each, of course, has responsibility to advance his own welfare. Beyond that, and yet a part of it, each has responsibility to the other and to society. Grave responsibilities for inculcating and developing professional consciousness in young members of the profession rest upon the educational institutions and professional societies. Various phases of such responsibilities have been stressed in the several sections of this report.

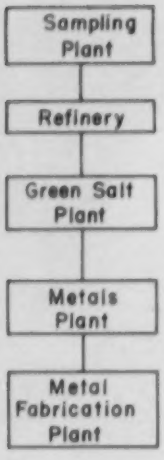
Without a sound technical foundation no man can become a competent engineer. But more than technical competence is demanded of one who expects to be recognized as a professional person. One must understand and observe appropriate ethical standards and it is important to cultivate proper understanding of such standards.

The ECPD program "The First Five Years of Professional Development" is an excellent step in the right direction. Here is opportunity for the engineering societies, the colleges, industrial management, and civic institutions to work together to aid young graduates in continuing their education and in adjusting themselves to conditions to be met in the practice of their profession.

The present report has been prepared with full realization that the subject refers chiefly to one phase of professional life. An attempt has been made to identify factors that have significant bearing on the specific problem under consideration. Concerted efforts by all concerned with advancement of the profession are required if satisfactory solution is to be found. It is believed that if the recommendations submitted are followed by those to whom they are directed, substantial improvement in the standing of the profession will result. There is no simple solution, but EJC recommends that:

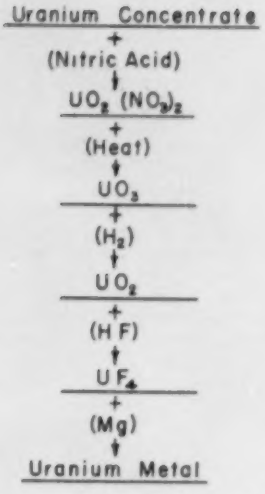
1. Management utilize the services of engineers more effectively and thereby afford them opportunity for advancement and economic improvement.
2. Management recognize its responsibility to make engineers feel that they are a part of management.
3. Management survey areas of communication, recognition, and salaries and, where found wanting, correct to conform with standards of professional practice.
4. The engineer take inventory of his services and his actions to make sure that he has a professional attitude toward his work.
5. Engineering societies establish and employ appropriate means to maintain high standards of ethical conduct for professional achievement.
6. Engineering societies encourage the professional development of their members and promote proper recognition of the profession.
7. Engineering educators emphasize the characteristics of the profession.

What Happens to U_3O_8?



Production of Uranium Metal

by D. S. Arnold, C. E. Polson, and E. S. Noe



REACTORS of today and tomorrow require a high uniformity of their fuel elements despite the wide variety of uranium raw materials from the far corners of the earth. To meet these quality standards metallurgists have been working to design production methods capable of yielding reactor feed materials whose maximum impurities are specified in parts per million, whose physical limits are expressed in thousands of an inch, and whose density variations are less than 1 pct.

Such requirements are necessary to maintain normal neutron flow in the atomic reactor and to insure that the isotopic content of the feed material is maintained within narrow limits.

Industrial scale output of uranium fuel elements necessitates complex processing to meet specification for atomic reactors.

Uranium ores and concentrates are produced in many sections of the world, including the Belgian Congo, South Africa, Australia, Canada, and the Colorado Plateau of the U. S. Ores from many of the larger deposits are relatively low grade, and these are concentrated near the mine site before shipment to refining centers, but high grade ores may be shipped directly to refineries.

Receiving and Sampling

These feed materials, received at the sampling plant in steel drums, are dried, milled, weighed, sampled, and analyzed as necessary for purchasing and process control considerations. Conventional methods are used except for the application of a higher degree of precision in measurements.

The various virgin feed materials, i.e., ores and concentrates, are blended among themselves and with materials produced in the metal recovery plant from scrap and reject fractions. Processing takes place according to the flowsheet.

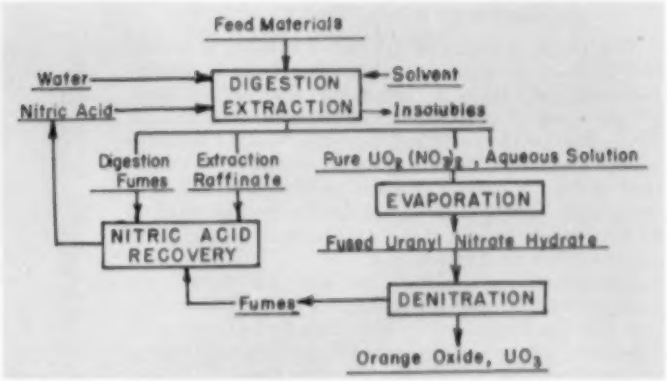
D. S. ARNOLD, C. E. POLSON, and E. S. NOE are with the National Lead Co. of Ohio, Fernald, Ohio.

Recovery and Purification of Uranuim

The uranium content of the feed materials is converted to soluble uranyl nitrate by digestion in nitric acid. The resulting slurry, consisting of acid insolubles and a digest liquor of metal nitrates and excess nitric acid, is pumped into pulsed perforated-plate liquid-liquid extraction columns in which the uranyl nitrate is preferentially extracted by a solvent mixture of tributyl phosphate and kerosene. Purification of the uranyl nitrate in the solvent extract stream from this primary extraction column is accomplished by a partial re-extraction or scrubbing of uranyl nitrate with water in a second pulsed perforated-plate column. The aqueous stream from this second column (scrub column) is recycled or refluxed to the top of the primary extraction column for uranium recovery. The purified uranyl nitrate is recovered from the organic solvent stream from the scrub column by re-extraction with pure water in a third pulsed perforated-plate strip column. The *stripped solvent* stream is recycled to the primary extraction column through a solvent treatment and storage system.

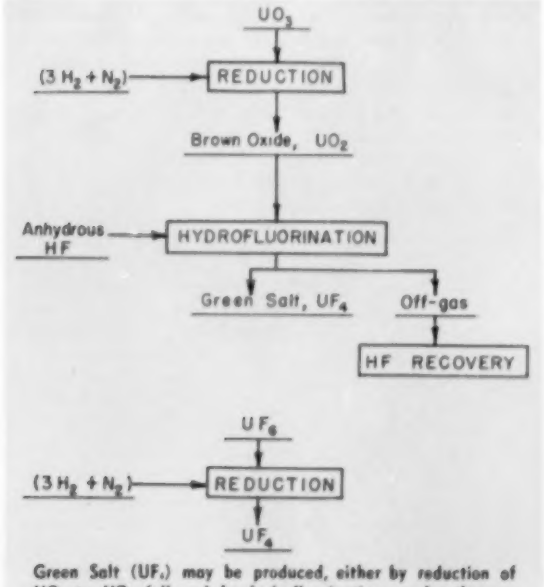
While the uranyl nitrate in the aqueous product meets chemical purity specifications (subsequent processing in general results in product contamination), the uranium is converted through a series of steps to anhydrous uranium tetrafluoride (UF_4), which is used for production of uranium metal by a thermite-type reduction. These steps include evaporation of the uranyl nitrate solution to produce a molten salt of uranyl nitrate hydrate, which is converted to orange oxide (UO_3) by calcination.

Elimination of impurities to produce pure uranium oxide is a key step in producing the metal. The simplified refinery flowsheet is shown together with the nitric acid recovery plant, which is essential to the economics of the process.



Nitric Acid Recovery: Because of the high cost of nitric acid compared with the other commercial acids, and because of the atmospheric and water pollution problems associated with disposal of nitrate and uranium feed material, operation of nitric acid recovery plant is justified. Facilities include equipment for evaporation of the residual free nitric acid from the raffinates from the primary extraction columns and equipment for calcination of the metal nitrates in the concentrated raffinate to produce metal oxides and a stream of oxides of nitrogen. Conventional bubble cap plate absorption towers are used to recover the oxides of nitrogen from the gas streams from the raffinate calcination, from the digestion of uranium concentrates, from the denitration of the uranyl nitrate hydrate, and from the nitric acid dissolution of impure massive metal uranium. A bubble cap plate fractional distillation column is used to concentrate the evaporator product stream and other dilute nitric acid streams. The nitric acid produced in the absorption and distillation towers is returned to the digestion area of the refinery for further use.

Production of Green Salt (UF_4): Green salt (uranium tetrafluoride) may be produced by reduction of orange oxide (uranium trioxide) to brown oxide (uranium dioxide) followed by hydrofluorination, as shown below. Complete reduction of the orange oxide to the brown oxide is essential for high conversions to the tetrafluoride. The reduction is accomplished with hydrogen produced by catalytic dissociation of ammonia, a convenient source of hydrogen of the high purity needed. Anhydrous hydrogen fluoride (HF) converts the brown oxide to green salt. The excess HF used to achieve high yields of UF_4 is recovered from the hydrofluorination reactor off-gas stream by fractional condensation as 70 pct HF (returned to the supplier and as anhydrous HF which is recycled to the process). A residue is removed from the noncondensible gas, neutralized in a scrubber, and ultimately discarded.



Green Salt (UF_4) may be produced, either by reduction of UO_3 to UO_2 followed by hydrofluorination, or by the gas phase reduction of UF_6.

Green salt may also be produced by the gas phase reduction of uranium hexafluoride (UF_6) with hydrogen. The use of dissociated ammonia is also applicable to this process, and the byproduct HF is recovered from the off-gas stream by condensation.

Reduction of Green Salt to Uranium Metal: Green salt is mixed with metallic magnesium and charged into a dolomite refractory lined *bomb*. The bomb is capped and placed in a Rockwell furnace where it is heated until the thermite-type reaction between the tetrafluoride and the magnesium is initiated. With the high heat of reaction and the rapid rate of reaction, the contents of the bomb are melted and the uranium metal flows to the bottom of the charge cavity where it solidifies into a massive metal *derby*. After the bomb is cooled, the contents of the charge are removed, and the derby is separated from the slag, cleaned, weighed, and transferred to the melting and casting area. The slag is crushed and transported in portable hoppers to the metal recovery plant for recovery of uranium values.

Melting and Casting: The cleaned derbies are charged into refractory-lined crucibles, and the loaded crucibles are placed inside the induction coil of a vacuum induction furnace. After the metal is heated beyond melting temperature, it is ready for tapping. A special jig opens the tap hole, and the metal runs through the bottom of the crucible into the mold below. The metal is allowed to solidify in the mold under vacuum and is kept in the mold under inert atmosphere until the temperature has dropped to a few hundred degrees Fahrenheit. Then the furnace shell is opened, the mold is taken away and opened, and the ingot is lifted out by mechanical equipment.

The top of the ingot is cropped to remove pipe and impurities. A sample is cut off for chemical and physical tests, and the surface defects are ground off. Then the ingot is taken to the rolling mill.

Fabrication of Reactor Fuel Elements

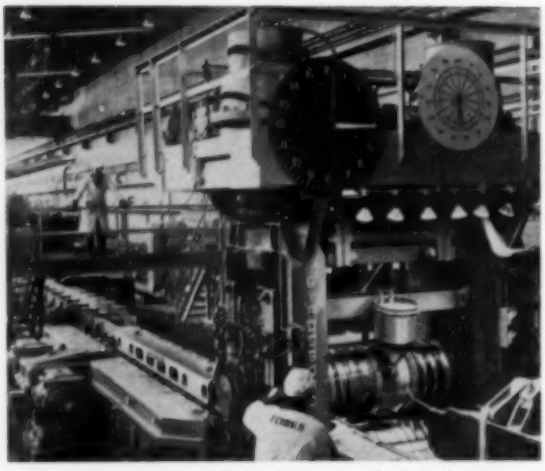
The ingot is charged into an electrically heated salt-bath furnace, and in about one hour it reaches the required rolling temperature. The heated ingot is conveyed to a primary mill where it is rolled, with frequent turning on the sides, into a billet. The billet is run through a series of stands that reduce the cross section to a round, which is sheared to the desired length and either allowed to cool to room temperature or charged into a third salt-bath for heat treatment.

The round rods, either heat-treated or not, are straightened by rolling through a straightener, and the ends are sawed off so only sound metal remains. The rods, six at a time, are fed into Acme-Gridley screw machines, which machine the rods to the desired diameter, and cut the rods into slugs. They are fed through centerless grinding machines, where the diameter of the slug is reduced to the final size, and then the ends of the slugs are machined on lathes and the corners rounded. The finished slugs are pickled in nitric acid, washed, dried, and inspected for surface quality and soundness. After inspection, the good slugs are packed and shipped.

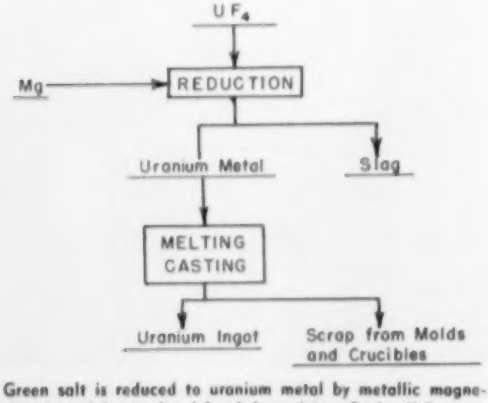
Recovery of Uranium From Reject and Scrap Materials

The bulk of the reject and scrap materials are produced in the metal reduction, casting, and fabrication areas. These materials may be grouped into two general types: 1) high grade metallic scrap, and 2) low grade and nonmetallic scrap. The metallic scrap consists of ends cut from the ingots and rods; sawdust, chips, and turnings from the machining area; and reject slugs. Where chemical purity permits, these are charged into the remelt crucibles with the virgin uranium derbies to produce ingots. When contaminated, they are processed in the metal recovery plant either by burning in a furnace to impure black oxide (U_3O_8) or by dissolving in nitric acid to form an impure aqueous solution of uranyl nitrate. In either case, the product is sent to the refinery as feed material.

The largest single source of low grade scrap is the slag fraction from the metal reduction step. Crucible and mold cleanings are burned and returned to the refinery as impure black oxide if they are of a sufficiently high assay; otherwise they are processed as low grade scrap. Uranium-bearing floor sweepings, dust collector residues, sump precipitates, etc. may also be included in this category. These materials are calcined in a furnace to oxidize residual free metal and burn organic constituents. The resulting furnace product is milled, acid-leached, and filtered to produce a uranium-barren filter cake and a uranyl salt solution filtrate. The uranium is precipitated as ammonium diuranate which is filtered on a precoat unit and converted to impure black oxide feed for the refinery by calcination of the cake in a direct-fired multiple-hearth furnace. A major consideration in the production in the metal recovery plant is the removal of chlorides and fluorides because of the increased corrosion these cause in the presence of nitric acid in the refinery.



This mill is used to roll uranium into rods for subsequent fabrication into reactor fuel elements.



Green salt is reduced to uranium metal by metallic magnesium in a dolomite lined bomb heated in a Rockwell furnace.

Quality Control and Accountability

Throughout all the operations, extreme care is taken to maintain the identity of all products for process quality control and to provide the basis for an active and accurate inventory of all uranium on the site. All storage and transfers of uranium and uranium containing materials accomplished in registered containers. The green salt is loaded into labeled cans, and the derbies made from the salt are numbered. The ingots are stamped with a number; the rods are stamped with a number identifying ingot number and rod position; and the slugs cut from the rods are numbered, identifying slug position, rod number and ingot. These numbers allow yield computation and tracing of the history of the slug back through the process chain.

Summary

An intricate series of process steps are required to produce uranium reactor fuel elements to meet the exacting product demands. A considerable amount of effort must be devoted to the recovery of excess reagents and of uranium from scrap and reject streams. Serious problems are encountered from the presence of corrosive reagents at elevated temperatures in two areas: the nitric acid recovery operation and the green salt reactors. These corrosion problems are met by careful construction and diligent process control. Although some new techniques are employed, basically the uranium production flowsheet consists of the application of a sequence of conventional industrial processes and operations.

Uranium Deposits of the Blind River District, Ontario

by Franc. R. Joubin and D. H. James

The present intense mining interest in this field is confined to a 500 square mile section where, early in 1953, the author commenced the successful search for and development of uranium deposits.

URANIUM exploration in the North Shore area of Lake Huron goes back to 1847 when J. L. LeConte, a distinguished American geologist, identified a pitchblende-like mineral which he called *coracite* from specimens sent from a locality north of Sault Ste. Marie. In 1948 a search for the LeConte occurrence resulted in discovery of the Camray field, some 70 miles north of Sault Ste. Marie. Prospecting the Camray field yielded about 30 pitchblende occurrences spread over approximately 200 sq miles. Almost without exception these discoveries consisted of narrow, short, pitchblende-filled fractures, within or along the contacts of diabase dykes cutting pre-Cambrian Archean granite and gneiss. Eight discoveries were diamond drilled and three were explored underground, but none proved to be of economic value. Uranium prospecting at this time spread far afield, and it was in 1949 that radioactive conglomerate was discovered in Long Township of the Algoma district midway between and 90 miles from Sault Ste. Marie and Sudbury. F. Joubin examined this discovery at that time but could not interest capital in its development.

F. R. JOUBIN has been President of Algom Uranium Mines Ltd., Managing Director of Pronto Uranium Mines Ltd., Rix Athabasca Uranium Mines Ltd., Rexspar Uranium & Metals Mining Co. Ltd., Buckles Algoma Uranium Mines Ltd. D. H. JAMES is an associate of F. R. Joubin.

Discovery of radioactive conglomerate on the then Fisher-Audette-Breton property was made in obviously leached, limonite-stained material in shrub-covered rock cuts that had been blasted about 30 years earlier during a period of base metal prospecting. Despite strong radioactivity over a large surface area, surface sampling produced only negligible uranium assays. This led to the assumption that the radioactivity was due almost entirely to thorium and the discovery reverted to obscurity over the following few years.

Several papers on the solubility and leaching of uranium outcrops, and conversations on the same subject with United Kingdom geologists personally familiar with such leached pyritic occurrences, prompted F. Joubin to re-examine the Long Township discovery in April 1953. Additional surface

The Pronto Uranium Mines Ltd. . . . the first of several large uranium mines to go into production in the renowned Blind River district of Algoma.

sampling again produced negligible uranium assays. The same material was then assayed for thorium and the negligible amount present voided the earlier condemnatory assumption. The paradox of high radioactivity, while uranium and thorium were relatively absent in the outcrop, suggested a buried or decay-product source for the radioactivity, presumably effected by surface leaching. Diamond drilling to depth was decided upon to test this theory and was immediately successful.

Diamond drilling also established that the uraniferous, pyritic conglomerate bed was large and basal to a particular arkose member of unique appearance. Subsequent reconnaissance prospecting of the base of this particular arkose, greatly assisted by Collins,[2] revealed the presence of similar radioactive, pyritic, basal conglomerate beds at several points over a distance of about 80 miles. These discoveries were protected by staking of 1500 claims, which precipitated the greatest staking rush that Ontario had experienced to that date.

Other prospecting teams, directed by F. Joubin, have discovered similar deposits in the Espanola district 40 miles to the east and in the Sudbury district 100 miles to the east, strongly suggesting that the uraniferous conglomerate type of deposit under discussion may prove quite common, at least to this general district.

In the two-year interval since the above discoveries were made six large uranium mines have been developed by diamond drilling. It is probable that an additional three mines will be developed during 1955. Present drill-indicated and reasonably probable ore reserves for this district already total about 150 million tons.

Geology

General geology of the Algoma district was mapped by Collins[3] and Eskola in 1914-1916. A limited amount of semidetailed and detailed mapping was undertaken by Abraham[4] along the South Belt during 1953. Much detailed but unpublished mapping has been undertaken during the past year by the mining companies active in the district.

Bedrock formations of the Algoma district are all pre-Cambrian in age and consist of sedimentary, intrusive, and metamorphic rocks. The assemblage is divided into two major subdivisions: basement rocks of pre-Huronian or Archean age, separated by an unconformity from the younger sediments, and intrusives of Huronian or Proterozoic age.

Basement rocks in the Algoma area consist of granite, granite gneiss, and highly altered layered types of medium to basic composition, in different proportions. Rocks of the basement series are of no present economic interest in so far as the uranium mineralization is concerned.

Rocks of Huronian age rest unconformably on, or intrude, the truncated pre-Huronian basement. The Huronian age sequence, after Collins, consists of the Bruce series on basement overlain unconformably by the Cobalt series.

The Cobalt series, consisting of a heterogeneous mixture of sediments, including conglomerate, greywacke, and quartzite, is of no present economic significance in so far as uranium mineralization is concerned, and details of lithology and stratigraphy are omitted here. This series is present only in the western portion of the synclinal area where it must be penetrated in uranium exploration of the underlying Bruce series.

Diamond drilling in the Blind River area. Geological Survey of Canada photo.

The Bruce series, and more particularly that portion of it immediately overlying the pre-Huronian basement, is the host rock to all uranium orebodies developed to date and therefore constitutes the principal target of all uranium exploration.

The Bruce series in the Algoma uranium district consists of sediments including boulder and quartz-pebble conglomerate, greywacke, argillite, arkose, quartzite, and limestone. It is the lowest formation of the Bruce series that is of prospecting importance for uranium. Certain higher limestone beds of the Bruce may prove to be of some economic importance as a source of lime reagent for the district's uranium leaching mills. The important basal formation of the Bruce is locally called Mississagi.

The ore-bearing Mississagi of the Algoma uranium district varies in thickness from 750 ft to 2500 ft. It consists predominantly of a characteristically green-colored, fine to coarse grained, cross-bedded arkose with minor amounts of greywacke, argillite, boulder conglomerate, and the important uraniferous quartz-pebble conglomerate. The quartz-pebble conglomerate always occurs at or near the base of the formation.

Intrusive Series: Intrusive rocks varying from acidic to basic in composition are present throughout the area as stocks, sills and dykes and appear to have been intruded over a protracted period dating from pre-Huronian to post-Huronian. The acidic rocks, in some instances at least, appear to be acidic facies of relatively basic types. Small dykes of pegmatitic to aplitic texture, often with closely associated quartz veinlets and accompanied by hematite-stained albitization, are not uncommon in the Mississagi sediments and basement rocks. In the few mine openings to date that expose for study a vertical section through the Huronian and into the basement rocks, there appears to be a relatively large quantity of the basic-acidic intrusive suite

grouped within and near the unconformable pre-Huronian contact zone.

Structure: Structural geology of the Algoma district is well shown on Collins' Blind River Sheet.[2] From this map it will be seen that there are present a shallow west striking synclinal structure, the Basin area, with a 5° plunge to west, adjoined to the south by an eroded anticlinal structure, also with a gentle plunge to west. These complementary structures are of about equal size, each measuring approximately 30 miles along the axis and about 10 miles in average width. In plan outline the outcrop trace of the Huronian and pre-Huronian contact forms a Z pattern.

The south flank of the anticline or lower limb of the Z is truncated by the only regional fault system recognized up to this time. This fault system, called by Collins the Murray fault in the Algoma district, is tentatively correlated by Thomson[5] and the writer with the Worthington fault system which splits the Sudbury Nickel Basin, 80 miles to the east, along its axis.

The amount of folding the Huronian sediments have undergone is conjectural. Except along the south edge of the syncline where cut by the Murray-Worthington fault, it appears that the Mississagi sediments and included uranium-bearing conglomerates now occupy attitudes not very different from those under which they were formed. Very striking is the similarity in size, distribution, and attitude of the Algoma ore-bearing conglomerates to the presently elevated, post-Pleistocene gravel beaches inland from the east shore of Lake Superior.

The concept that the present distribution of these sediments simply marks the original depositional basins and bays, with a minimum of subsequent distortion, is held by several field geologists, including R. C. Hart[6] and S. W. Holmes,[7] who have devoted much study to the subject.

Ore Composition and Characteristics

Ore material of the Algoma district consists of uranium and minor amounts of thorium, mainly in beds of pyrite-bearing quartz-pebble conglomerate. Smaller, but still important, quantities of ore occur in grey, but more commonly red, albitized arkosic grit. Uranium in unidentified form is also found with chalcopyrite as a fracture-filling material in a diabase sill on one prospect, while in another locality it is present as mineralized breccia material in a fault zone. The last two occurrences are of no economic importance as yet.

The ore considered as typical Algoma because of its extensive distribution, large volume, and markedly uniform characteristics, is the pyritic quartz-pebble conglomerate. In this conglomerate the quartz pebbles average about ¾ in. diam and are well rounded although now minutely fractured. The matrix is green chlorite-sericite, comprising about 35 pct of the conglomerate's total volume. The matrix contains pyrite as bedded streaks of discrete grains comprising about 5 pct of the conglomerate by weight.

Uranium-bearing minerals are disseminated uniformly throughout the conglomerate matrix and in order of importance consist of brannerite (the uranium titanate, containing about 40 pct U_3O_8) uraninite, pitchblende, and thucolite. The brannerite occurs as fine grained wispy cloud areas comprised of tiny prismatic crystals often closely associated with anatase and pyrite. Small amounts of chalcopyrite, galena, specular hematite, molybdenite, rutile, scheelite, cobaltite, magnetite, and gold have also been reported present in the ore and occasional grains of detrital monazite have been recognized.

Average uranium content of these conglomerates is between 2 and 2.5 lb U_3O_8 per ton.

Uraniferous quartz pebble conglomerates are extensively distributed. They occur at or towards the base of the Huronian (Mississagi) arkose and the Huronian basement and have average dips of between 20° and 30°. Orebodies, which consist of the entire conglomerate bed, vary from 7 to 12 ft thick and continuous ore lengths range from 4500 to 7500 ft. Ultimate slope lengths of the ore areas are unknown but three important orebodies have been developed successfully to slope depths exceeding one mile. The most intensively developed northern section of the district, now explored by over 150 diamond drillholes, appears to be completely underlain by ore over an area of at least seven square miles. Although several conglomerate beds may overlie each other (separate by arkose) and all be uranium-bearing, usually only one bed in a given area will contain sufficient uranium to be of ore grade. In two large ore areas, the ore bed is the topmost one while in two other important ore areas the ore bed is the lowest of several.

Origin of the Deposits

Like the gold and uranium-bearing conglomerates of the Witwatersrand of South Africa, which the Algoma ores resemble, origin of the contained minerals is debatable and theories range from the detrital placer concept to outright hydrothermal. This writer feels that data are still inadequate to explain plausibly the source and extensive distribution of the minerals present. At the same time there is a fast accumulating mass of facts to indicate that, regardless of the source of the metals, hydrothermal fluids have been present and active in and near the uraniferous conglomerates and have undoubtedly affected their present distribution and form.

Economic Aspects

The large size of the individual ore masses developed, the frequency of their occurrence in an area of several hundred square miles, the simple metallurgy of the ores, and the remarkable accessibility and low cost nature of the area all contribute to mark the Algoma uranium district as one of world importance.

After less than two years of mining development six mines are assured, while three more are expected to develop to that stage during 1955. Initial production rate for the first four mills, now in various stages of construction, will be 12,500 tpd. The first of these large mills, the Pronto, commenced production in September 1955.

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Economic Determination Of A Mining And Milling Project

by James Boyd

ALL mining and milling enterprises must be based on adequate ore reserves. Reserves must be established by physical exploration, and the orebody should be of sufficient size and grade to insure recovery of capital invested in mine purchase, development, and mill construction and to provide a reasonable profit. Determination of these economic factors is so complicated, and present costs of mine development and construction so great, that analysis can be made only by competent persons qualified by experience in this field.

What rate for maximum efficiency?

Unfortunately, even today mills are built before deposits have been adequately outlined, and there are rusting monuments to such folly in nearly every mining region. Also there is a tendency to be guided by the philosophy that "if a little is good, a lot is better," which leads to the conclusion that mining at a given rate and making so much per ton will yield a profit of so many dollars per day. Consequently, why not build a mill to treat twice as much per day and make twice as much money?

For each orebody, however, there is a rate of maximum efficiency at which it can be profitably mined. A rule of thumb used by some engineers is that mill capacity in tons per day should not exceed one third of the ore tonnage per vertical foot in the orebody. In other words, experience has shown that the maximum rate at which a mine can be deepened is equal to mining the stoped areas one third of a foot per day. This rule can be applied only with stringent reservations and can not be applied to massive low grade deposits.

Volume of a deposit is important; geologists and examining engineers refer to *measured, indicated,* or *inferred* reserves. Estimated recovery of capital investment plus a minimum profit should be based solely on the measured ore, and the degree of speculation on the eventual profits should be based upon the indicated or inferred reserves. Orebodies, however, occur in such wide variety of geological settings that it is impossible in a short article to establish for all cases the adequacy of development or the geological reasoning for placing reserves in the various categories. Estimates of ore continuity in areas that cannot be reached by sampling must be based on experience with the type of occurrence under examination. Thus density of drill spacing, or the number of faces to be exposed for sampling by development openings, will depend on continuity of the orebody, and the determination of how much development should be done in advance of mill construction is a part of this same problem. Fortunately most competent examining engineers have enough experience to evaluate these factors, and the minerals industry has an extensive background upon which to base a reasoned appraisal. Consequently, it is not difficult to reach a logical conclusion, based upon both fact and judgment.

Ore grade required to make a mineral deposit a profitable venture presents an exacting problem in economics, involving factors beyond the total market price of the valuable mineral content. Foremost is the amenability of the ore to beneficiation by standard methods. This can be determined only by testing in the laboratory and by pilot operations, and it is important to remember that few ores can be economically treated for 100 pct extraction. Ignoring this recovery factor is one of the most common mistakes made in evaluation. Time and again valuations have been made on the assay content of the sampled orebody without consideration of the recovery factor. Similarly, a factor should be determined for dilution of grade resulting from the inevitable inclusion of wall rock in the mined ore. Because no two orebodies are completely similar, at the mining stage some experimental stoping should be undertaken (if possible) to determine a dilution factor. Obviously construction of a mill should not be contemplated without thorough pilot plant testing to determine the most effective flowsheet.

Economic realization vs Assay value

Mill concentrates, except in nonmetallic mining operations, are rarely delivered to the ultimate consumer. They must be marketed through smelters or refineries, which usually service a number of mills. Generally such smelters, in order to be profitable, must operate on a large scale, and it takes an equally large mill to justify its own smelting or refining unit. Except for government operations—uranium for example—smelters do not publish a tariff and the mine operator must negotiate with the smelter most favorably located in terms of transportation from the mill. In some instances, as with copper, a specific mill concentrate may command a better price from one smelter than from another. If the major customer of a smelter ships a highly basic concentrate, the smelter often pays a premium for acid ore, or vice versa. Freight cost to various smelters must, of course, be balanced against the obtainable smelter settlement. It must always be remembered that there are metal losses and treatment charges at this state that vary greatly from one metal to another,

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so that realization is greatly decreased. With some metals, such as zinc, economic realization from the original assay value to the final marketable product can be quite low.

Estimating the anticipated metal price to be obtained throughout the life of the property is the next step. A mining venture is normally expected to recover invested capital over a long period of time. Consequently, prognostications of price levels cannot be avoided, and the risk involved is inversely proportional to conservativeness of price estimates. Finally, calculation of the costs of mining, milling, transportation, and marketing are absolutely necessary to complete such a study.

Fortunately, there has been sufficient experience in the mining business over the years to permit cost estimates with reasonable accuracy, assuming that the mining methods and metallurgy follow reasonably standard procedures. If, however, the anticipated metallurgical process or mining method is new or untried on a production basis, estimates of plant costs and operations may be hazardous. For example, it has recently been published that a new plant, built in Canada to treat concentrates from a nickel mine by pressure leaching instead of the conventional smelting process, cost $7 million more than the original estimate. This is 20 pct of the original estimated cost of the whole project. This is typical of the risk involved where new processes are being used.

Tested processes mean accurate cost estimates

Examples from Kennecott's experience might be appropriate. The Sorel plant of Quebec Iron and Titanium Corp. utilizes a smelting process entirely different from any previously used in treatment of titanium-bearing ores, and the cost of the plant to date has been even more substantially above the original estimates. On the other hand, Kennecott's new Utah copper refinery, which utilizes long established principles and practice, was built for almost exactly the estimated cost.

This brings to mind another factor that may require careful evaluation. There are times when costs of a patent or proprietary rights to a complex metallurgical process may make or break a new enterprise. Should the investor risk experimenting with a new or untried process? A gamble on this basis may well run into millions of dollars, especially if further new developments were to make the process obsolete overnight.

Other cost factors may involve water. There may be a serious water shortage or, conversely, dangers of flooding. Dust hazards, air or water pollution, and tailings and waste disposal may become all-important cost items, especially in densely populated areas.

Even if a new plant does not use new processes, it is wise to have available sufficient capital to tide the operation over the first months of profitless or deficit operations before smelter or product returns begin to flow. Time is required to develop and bring a mine into production, and during this period interest charges can become a big item. It has often been said that there are five years between discovery and dividends; many mines have required much longer.

When size, grade, and metallurgical treatment of the orebody have been determined, other economic factors must be evaluated—not the least of which are markets. Metal prices have shown a long range increase comparable to other price increases, but metals usually have price volatility not found in other commodities. Here again, there must be sufficient capital to carry a long-lived operation through inevitable periods of depressed prices. Fortunately in mining, despite wide fluctuations in short-term demand, requirements for virtually all mineral products have continued to rise throughout industrial history, and since they are wasting assets, new producing units are continuously necessary to replace those becoming depleted. During the past decade the mining industry, with few exceptions, has been struggling to satisfy industrial and military requirements. There seems little likelihood that this picture will change.

A check list for the firm making foreign investments:

If the contemplated operation is to be located in a foreign country, taxation, import and export duties, and exchange regulations must be reviewed. Some legal corporate questions that must be resolved are:

Is the exporting of metals and/or mineral products prohibited or restricted by administrative measures or taxes that might result in suspension of exports? Is domestic sale at price levels less than world prices, and is payment by barter, or in currencies having no validity in international payments?

Do free market rates of exchange apply to all transactions between local and U.S. or other foreign currencies?

Will the enterprise be allowed to retain abroad in U.S. dollars or other foreign currency the revenue from its sales outside the country?

What will be the impact of local income taxes? Is there a convention between the U.S. and the foreign country eliminating double taxation? Does the country recognize depletion? Is there a moratorium on income taxes during the early life of the operation or until the investment is returned out of income?

Will there be taxes and duties on the importation into the country and installation of plant, machinery, equipment, and stores for establishment and maintenance of the enterprise?

Will the enterprise be allowed to employ the necessary foreign technical and administrative staff, and will it be allowed to pay them wholly or partly in foreign currency?

Will there be freedom to promote the enterprise along sound technical and administrative lines without interference from government departments?

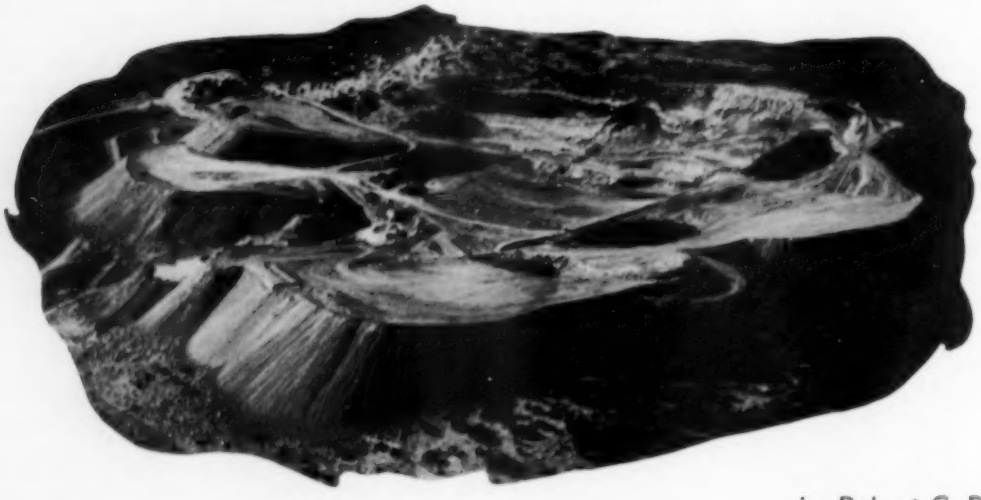
What will be the legal status of the enterprise in the country where the work is to be done? Is it required to incorporate there even when most of the capital is supplied? Must foreign directors control or outnumber its directors on the board of this corporation? Would they determine the distribution of profits?

It is seldom that one individual has the ability and knowledge to make such an evaluation. Fortunately, human experience is broad and there are those who have gained sufficient knowledge from their predecessors to bring expert judgment to bear on most mineral enterprises. No investor, however, should undertake to reach conclusions on a new minerals venture without employing those with experience to advise him.

Underground Or Open Pit?

Continental Uranium establishes criteria for calculated risks — the decision:

Strip Mining at the Deep North



by Robert C. Pruess
C. H. Reynolds

LATE in 1954 exploratory drilling indicated a substantial orebody on the Rattlesnake claims of Woodmont Inc., a Continental Uranium Inc. subsidiary. Woodmont holdings are located about 35 miles southeast of Moab, Utah. Only a few miles north of Big Indian Valley and other Chinle-sand uraninite deposits, the claims are in an entirely different geologic environment.

Detailed development drilling continued until the Deep North orebody was outlined, covering an area approximately 300 x 450 ft. All exploratory drilling and about 80 pct of development drilling was wet core. Chemical assays for each hole sample, applied at 1-ft intervals against the measured core length, were put into a conventional ore calculation formula. Forty-six holes were drilled to delineate the Deep North orebody.

Simultaneously with the unfolding development on the Deep North orebody, mine planning progressed. A rigid comparison chart was set up and continuously revised between conventional Plateau underground mining and the possible strip approach. A test pit project mining a small Salt Wash pod adjacent to the Deep North had been illuminating. This original orebody was fairly continuous but exhibited bad backs, and overburden averaged 25 ft deep. This test pit had recovered 300 pct more tons and about 350 pct more U_3O_8 than was estimated for underground methods. This added production came primarily from the 100 pct extraction and the myriad small ore pods orbiting about the normal Salt Wash rolls. To a lesser degree added tons were gained by a more favorable economic balance which allowed mining more low grade fringe ore. Also on the test pit the overall company net return after taxes compared more favorably per dollar expended than would be possible with conventional underground mining.

As mine planning advanced, it seemed radical to strip an orebody averaging 170 ft deep with a probable waste-ore ratio of 25:1. However, the very favorable economic picture gained from the dry run test pit exerted a powerful influence, and the mine planning research was continued. Mine operators were consulted for advice on costs, operational experience and especially for ideas delimiting the unknown, but conditions at these operations did not parallel those at Continental. No one was coping with overburden similar to the plastic Brushy Basin clays and flat-bedded siltstones. Therefore, Continental had to establish criteria for several large calculated risks. All influencing factors were studied and their effect calculated and graphed.

Some of the unknown or difficult to delineate items were the competency of the Brushy Basin

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Ground Factors

1) Calculated ore reserves and distribution as well as fringe ore and orbiting pods.
2) Configuration and depth of overburden.
3) Dump area required.
4) Solidity of yardage estimates.
5) Method of calculating yardage removed.

Cost Factors

1) Contract price for strip.
2) Firmness of contract bid price.
3) Financing and interest costs due to investment tie-up.
4) Lower cost of underground ore adjacent to pit bottom.
5) Cost of access and mining and recovery of orebody by conventional underground methods.
6) Royalties.
7) Engineering and supervision required.
8) Extra drilling cost necessary to block out positively.
9) Effect of weather on the overall open pit mining costs.
10) Pro rata general and administrative costs and overhead.

Operational and Management Factors

1) Relative time required to mine the orebody by underground or by strip methods.
2) Taxes.
3) Title and legal ramifications of putting roughly three-quarter million dollars in the ground before any ore was mined.
4) Auxiliary company plans.
5) Additional ore supply on projected mill plans.

formation, the prediction of safe back slopes, the effect of unknown fault planes or joint structures unseen on the surface, the extent and effect of the filled surface joints which had been encountered in drillholes, and the fallacy of the human being.

In June 1955 it was decided to strip mine the Deep North orebody. Nine firm bids taken on the project ranged from $0.29 to $0.72, the majority at $0.50. A detailed contract was signed with Daniels Construction Co. of Allison and Haney, Albuquerque, N. M. A minimum monthly requirement of 200,000 yd was mandatory to enable pit production to dovetail with company financing and mill plans. Work has progressed satisfactorily. As of Jan. 1, 1956, 1,529,448 yd had been removed of an estimated 2½ million yd.

One additional cost factor has affected the company to date, namely, a strong, steeply dipping fault plane uncovered on the northwest pit wall. This necessitated removal of roughly an additional 100,000 yd. Two factors have affected the contractor to date. The first was the extent of the large outcropping rock-filled joints, remnants of ancient landslides. This necessitated moving in Euclids and shovels to replace the tractors and carryalls originally designed. The other factor was the thickened, indurated siltstone layer encountered at about 75 ft over the ore in part of the pit. This is requiring blasting and use of the shovels and Euclids. However, the project is progressing satisfactorily, and is expected to be onto the ore well ahead of schedule.

Major stripping operation in progress at Continental's Deep North orebody is expected to increase yield greatly.

Uranium in Canada

by A. H. Lang and H. R. Steacy

GROWTH of general interest in uranium during the last ten years has been unparalleled in mining history, outranking the popular gold rushes and mining booms of bygone years. This is not surprising, considering the spectacular advances in nuclear research and the fact that a small amount of uranium can provide great quantities of energy for peaceful purposes. There are, however, a number of misconceptions and exaggerations regarding uranium. Many novices have highly exaggerated ideas of the ease of finding workable deposits, as opposed to mere occurrences, and reports of insignificant discoveries are sometimes given much publicity.

Beginning about ten years ago mining for uranium has assumed a major place in Canadian and U. S. mineral industries. Uranium is now high on the list of metals produced in Canada. The gross value of uranium production in Canada in 1958, when additional plants now under construction are operating, will probably exceed 180 million dollars.

Pitchblende, the principal mineral for uranium and radium, was first recognized in Czechoslovakia more than 200 years ago, and the first occurrence in Canada was found about a century ago on the shore of Lake Superior, some 80 miles north of Sault Ste. Marie. A collection of minerals had been made by Captain Stannard, skipper of a schooner belonging to the American Fur Co. The collection was found to contain a specimen of pitchblende, and this information was published in various reports. Several attempts were made to rediscover the locality, after radium came into prominence, but these were unsuccessful until recently.

From time to time during the last century, occurrences of other uranium minerals were reported from different parts of Canada, but none proved of more than scientific interest until 1930, when an important pitchblende deposit was found at Great Bear Lake, almost on the Arctic Circle. This discovery and the subsequent mining operation are highlights in the history of Canadian mining. They mark one of the first successful uses of seaplanes in connection with prospecting and mining, and the mine is the world's most northerly underground lode operation.

In 1900 two young geologists made a reconnaissance of Great Bear Lake by canoe for the Geological Survey of Canada and found indications of cobalt and copper on the east shore. This information was published in the usual way, but prospectors did not respond to it quickly because the region was remote. In 1930, soon after the use of seaplanes began to revolutionize exploration and prospecting in northern Canada, G. A. LaBine and E. C. St. Paul, two experienced prospectors, flew to Great Bear Lake on a prospecting venture, with the reported cobalt-copper locality in mind. They found it, and discovered that it also contained pitchblende, which LaBine recognized. At that time uranium was of no commercial value and the deposit was opened up as a radium mine, called the Eldorado after a company of that name which LaBine had previously organized in connection with a gold deposit in Manitoba. Production was begun in 1933 after an extraordinary amount of pioneering, necessitated by arctic conditions and the fact that supplies had to be transported by barges on a water route 1350 miles long

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extending from the railhead north of Edmonton, down the Mackenzie River system, and thence up the Bear River and across Great Bear Lake. Part of this route had been pioneered by the Hudson's Bay Co. to service its trading posts, but the part up Bear River and across the lake had to be established for the first time. A complete transportation system of tugs, barges, and portages is now operated as a subsidiary of the Eldorado Co., serving many private ventures, towns, and military installations between the railhead and the Arctic Ocean. Concentrates are carried south to the railway by barge or by air, and thence to a refinery built by the company in Ontario, after much research had resulted in a suitable refining process for the radium.

Uranium is much more abundant than radium in pitchblende and several other minerals, but uranium was almost valueless until the development of atomic fission during World War II. Then, although important quantities of uranium were obtainable in Belgian Congo, it was obviously desirable to have adequate supplies on this continent, so authorities in both the U. S. and in Canada began special programs to expand production in each country. In Canada, as a security measure, private staking and mining for radioactive minerals were banned, the Eldorado Co. was operated for the Canadian Government, and later acquired by it, and an extensive campaign of geological studies, prospecting and exploration of prospects was begun by Eldorado with the assistance of the Geological Survey of Canada. Many additional uranium occurrences were found, particularly in northern Saskatchewan. Efforts were concentrated there because it was the only district in Canada, other than Great Bear Lake, where pitchblende was definitely known to occur; it had been found in 1935 at a gold prospect and was confirmed in a geological report of that period. The region is much more accessible than Great Bear Lake, although several hundred miles by water from railhead. In the intensive campaign that began in 1944, geologists and engineers selected the places for prospecting and appraised discoveries, and men previously experienced in prospecting for gold and other metals, or newly-trained men, used time-honored methods of prospecting supplemented by portable geiger counters developed and built by a joint project of the National Research Council and the Geological Survey. In this way more than 1000 pitchblende occurrences were found in northern Saskatchewan alone, most of them small and probably not worth mining. Testing consisted of a process of elimination whereby a little stripping and trenching were done if necessary to provide better exposures; the better showings were probed at depth by preliminary diamond drilling; detailed drilling was done where warranted; and, finally, a few prospects that showed best results on drilling were explored further by underground methods. In this way one large mine, the Ace, was proved by 1951 and brought to production in 1953, after much transportation and construction under difficult conditions and much research to develop a treatment process suited to the ore.

Part of Gunnar mine plant, Saskatchewan.

Treatment plant at the Pronto mine, Blind River area, Ontario. View taken from headframe of shaft.

The Ace was discovered by a team of experienced prospectors named P. St. Louis and E. Larum, under the general supervision of Eldorado engineers. The surface exposures were not as impressive as several others found in the district, but the Ace showings and the neighboring territory were selected for thorough drilling because the geological structure was theoretically favorable. The decision was amply vindicated, and the results stand as an example of the application of sound geological guidance for prospecting and exploration. Eldorado claims extend six miles along the favorable structure outlined, and continued drilling and underground exploration along it have revealed additional ore which led to a recent decision to enlarge the treatment plant to handle 2000 tpd.

At the end of 1947 the Canadian government, on the advice of the Atomic Energy Control Board, took

steps to permit prospecting and mining for radioactive materials by private individuals and companies, thus initiating a widespread boom in prospecting, staking, and testing prospects. A relatively small number of participants were experienced prospectors and mining men. Most were inexperienced, and the results have demonstrated the importance of experience. As it became apparent that private prospecting and mining would provide adequate additional supplies of uranium, Eldorado gradually withdrew from prospecting and from testing new properties, and the Mines Branch and Geological Survey of the Department of Mines and Technical Surveys, as well as mining departments of some provincial governments, made special efforts to undertake research and to provide publications and sample-testing services useful to prospectors and companies. However, no reward was offered for a new discovery, no undertaking was made to examine or test discoveries on behalf of the discoverers or claim owners, and no direct financial assistance was offered. Prospecting and mining for uranium was encouraged by guaranteeing a price for acceptable ores and concentrates until 1962, on schedules comparable to those of the U. S., and by offering to consider special purchasing contracts to meet special conditions. The results are that there are now several thousands of additional discoveries, in many parts of Canada, bringing the total of known occurrences to about 8000. Most of these are, naturally, too small or too lean to be worked, but there are several outstanding privately owned mines now in production or for which production is assured, a few minor producers, and several favorable prospects.

The first private discovery to show outstanding qualities was the Gunnar, which was found in the following way. In 1949 the Government of Saskatchewan withdrew the unstaked parts of the Beaverlodge region from staking and issued concessions, most of which comprised 25 square miles. All concessions expired in 1952, after which those holders who had completed the requirements were permitted to hold a proportion of the ground as claims, and the remainder came open for general staking in August 1952. A concession covering part of Crackingstone Peninsula, 20 miles southwest of the Ace deposit, had been abandoned earlier—after inadequate prospecting, as was later apparent—and this ground was open for general staking in the spring of 1952. At that time, two experienced prospectors, A. O. Zeemel and W. J. Blair, in the employ of Gunnar Gold Mines Ltd, for which G. A. LaBine was president, began careful prospecting in this area, which was one of the few places in the region that were open for staking at the time. The area was underlain largely by gneisses not then regarded as being among the more favorable rocks of the district. These prospectors found a strongly radioactive outcrop, a few small pieces of radioactive rock that had been pushed to the surface by frost action, and discovered that a large area covered by overburden was highly radioactive. A grid survey was made by taking readings with a scintillation counter at 50-ft intervals. A plan showing radioactivity contours, and samples from the outcrop, was considered sufficiently favorable to warrant diamond drilling. Vertical holes were drilled at 75-ft intervals, the radioactivity plan being used as a guide in outlining roughly the area to be drilled. As a result, a very large orebody was outlined. The information obtained by drilling, and that from a large bulk sample taken from the outcrop, were considered sufficiently consistent to warrant a decision to prepare for production, without further underground exploration. In 1954 the deposit was estimated to have a gross value of 130 million, and the owners contracted with Eldorado for delivery of concentrates to the value of about 77 million. A large open pit operation was prepared, a 1250-ton treatment plant was built, and production began in 1955.

Outstanding developments have also taken place in the Blind River region east of Sault Ste. Marie, Ont. These are linked with the early reports of an occurrence of pitchblende at Lake Superior. The intensive private prospecting that began in 1948 caused renewed interest in this almost legendary occurrence, and in the autumn of 1948 an experienced prospector, Robert Campbell, found pitchblende on the shore of Lake Superior corresponding closely with the original description. Much staking and prospecting followed and several pitchblende occurrences were found, although none has been considered large enough for production. At this time Karl Gunterman, a prospector, tested some old specimens in the local Mining Recording Office and found that one labelled Long Township was radioactive. This township is about 100 miles southeast of the Lake Superior occurrence. Gunterman searched here and found the radioactive conglomerate at a few old trenches excavated years before in testing an occurrence of iron pyrites. He staked claims, and the property became known as the Breton. Several geologists and engineers examined it, but their samples yielded low assays. Better assays were obtained from a small discovery a few miles away, and when these results were published by the Geological Survey in 1951, Franc Joubin, a geologist of long experience in prospecting and mining, took a renewed interest in the Breton occurrence, which had been allowed to lapse. It was staked by Joubin and his associates in 1952. Joubin reasoned that the low assays, despite fairly strong radioactivity, might indicate that uranium had been leached selectively from the surface exposures, leaving behind the more

A little on the light side.

Popular interest in uranium has deluded many persons, and cranks of various kinds have entered the field. There have been requests to investigate places where there is unusually poor radio reception, where rocks glow in the dark, where snow melts as fast as it falls, or where the rock is so radioactive that it sets the forest afire, and also requests for information on geiger counters that will find gold and other nonradioactive metals. Persons are still interested in springs containing traces of radioactive salts, and in buying uranium ore to cure rheumatism. Men offer to use secret devices that will find uranium in the field, or even over a map in the office, and the most advanced practitioners do not even require an instrument, but make the selection by a new technique called mental geophysics. One of the most colorful of these visitors was referred to us by a representative from another country; the following day an apology was received with the explanation that further reports from the homeland indicated that the man had escaped from an institution.

active radium. Preliminary diamond drilling was undertaken, and the fourth hole yielded a favorable intersection. Subsequently, an extensive program of drilling outlined a large low grade orebody, attractive because of its accessible location.

As shown on a geological map published by the Geological Survey, the conglomerate lay along a contact extending many miles. Before releasing news of the first significant drill intersection, therefore, Joubin and his associates organized teams of prospectors equipped with counters and flew them to lakes along the contact. As a result, several additional discoveries were made and large blocks of claims were staked. Drilling at one of these, at the Quirke Lake property of Algom Uranium Mines Ltd, has revealed a very large deposit, and drilling near the same contact on another group of claims held by the same company, without surface exposures, has revealed another. Still another has been demonstrated by drilling on the claims of Consolidated Denison Mines Ltd. Contracts totaling nearly 450 million have been made for delivery of uranium precipitates from the Algom, Denison, and Pronto properties. The Pronto plant is already in production and the others are scheduled for production in 1956 and 1957. In addition, several other companies are exploring prospects along the Blind River belts.

The southern part of the Canadian Shield, in Ontario and Quebec, has long been known to contain occurrences of uranium-bearing pegmatitic deposits, and the intensive prospecting during the last few years has resulted in the discovery of many additional ones. Almost all of these are small, or of sparse or erratic uranium content. However, a series of pegmatitic deposits found near Bancroft, Ont., by G. W. Burns showed larger combined tonnage and more attractive average uranium content than most pegmatite deposits. Mr. Burns is a part-time prospector who qualified himself by reading all the literature he could obtain on prospecting. He recognized favorable indications as described in the government booklet on prospecting for uranium, and he proceeded in a manner that testifies to the soundness of his self-training. His property has been amalgamated with neighboring claims to form the Bicroft property. In 1955 sufficient ore was proved to warrant a contract for delivery of uranium oxide to the value of about 35 million, and a 1000-ton plant is expected to be in production in 1956. Some additional pegmatite deposits are showing promise, but in general, most such occurrences are unfavorable.

In addition to the successful side of the story, there is also an unsuccessful side. There is now about one producing mine or assured producer and one outstanding prospect for every thousand known uranium occurrences in Canada. There are also other prospects that may respond to further testing, but the ratio of important discoveries to unimportant ones is certainly far less than 1 to 100, because nature made mineral occurrences in all sizes and degrees of richness, and only the best will repay the cost of mining. Although accurate figures are not available, this principle holds true for prospecting and development for any metal, and in any country; the ratio is probably a little more unfavorable in the case of uranium because geiger counters and other instruments permit detection of very minor occurrences that might otherwise be passed over. Experienced prospectors and mining men know these odds and take them in stride, concentrating their efforts on discoveries that have a chance. One of the greatest of mining engineers states in his recently published memoirs that mining is no place for the unwary, a maxim that can be recommended to prospectors for uranium. Although it is not impossible for a novice to find an important deposit, the overwhelming number of insignificant occurrences makes the chances remote indeed for the inexperienced and uninformed, who have no knowledge of how to distinguish a prospect from a mere occurrence. If a beginner does find an exceptional occurrence, he may have difficulty in convincing a mining company

Fay shaft, Eldorado Mining & Refining Ltd., Beaverlodge, Saskatchewan.

or a government official because so many have *cried wolf* before him, and because he does not know how to take proper samples or prepare a prospector's report that would command attention. Would-be prospectors, even part-time ones, will therefore be well advised to attend courses, study diligently the literature on prospecting, and obtain experience before considering themselves qualified. It should also be remembered that mining for uranium in Canada has been done on a substantial scale. Deposits found have not been adaptable to small-scale mining like some of the operations on the Colorado plateau.

The manner of discovery and development of principal Canadian deposits shows that results can be obtained both by the organized prospecting campaigns carried on by government authorities during the period of secrecy and by the more usual system combining independent competent prospecting, mining company operators, and government services.

Uranium mining now has an established place in Canada's mining industry. Reserves of uranium ore now proved at several deposits in Canada assure large production and a continued place among the leading uranium producing countries. It was announced recently that additional contracts at special prices probably will not be negotiated after March 1956. Prospecting and exploration for the next several years will probably be focused on finding and proving high grade and readily treated deposits that have a chance of being worked under the guaranteed price schedule. This would emphasize still more the need for knowledge of how and where to prospect and for experience in judging discoveries. Canada is providing a substantial part of the uranium being used today and will soon supply still more. Canada is fortunate in having large areas that have not yet been prospected exhaustively for uranium and for other metals.

Metallurgical Treatment Of Uranium Ore

by William L. Lennemann

CHEMISTRY of uranium with respect to its hydrometallurgical recovery from carnotite ores was investigated and well defined during the radium boom period between 1900 and 1920. Since that time, methods used to extract uranium from its ores have remained basically either acid leaching or sodium carbonate leaching. Until about 1950, the only practical methods known for achieving a better than 75 pct U_3O_8 concentrate from the leach liquors involved fundamental chemical techniques for either purifying a solution prior to the uranium precipitation, or refining a crude uranium concentrate that was produced by neutralizing a pregnant mill liquor.

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Since 1950 ion exchange techniques for uranium recovery have been well developed and put into operation in uranium milling circuits. In this process, uranium ionic complexes in the sulfuric acid leach liquors are selectively adsorbed on strong base anion exchange resins. Such resins include Rohm & Haas IRA-400, Permutite SK, and Dowex II. Uranium complexes adsorbed have been determined to be the uranyl disulfates and trisulfates. After the resin has adsorbed its capacity of uranium, the uranium is removed from the resin by a chemically adjusted eluting solution. Eluting solutions most commonly used are the acids and sodium and ammonium salts of

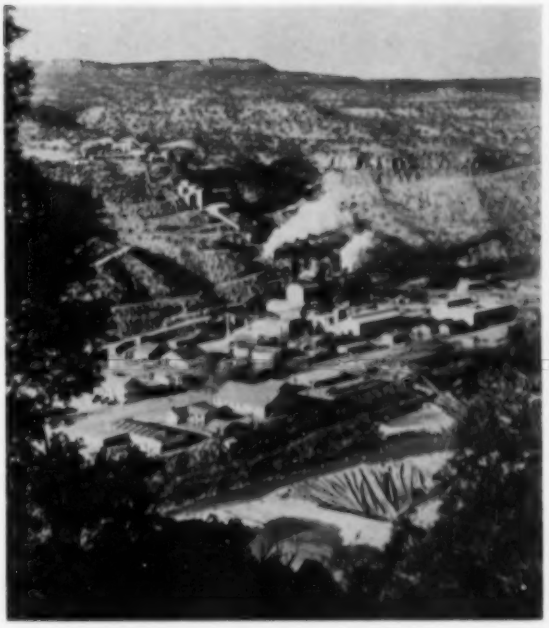
Table of the Western Uranium Mills and their Respective Processes,* Jan. 1, 1956

Reference Year†	Mill Location	Operator	Vanadium Recovery	Circuit	Ore Pretreatment
1947	Naturita, Colo.	Vanadium Corp. of America	Yes		Salt roast
1947	Rifle, Colo.	Union Carbide Nuclear Co. (formerly United States Vanadium Co.)	Yes		Salt roast
1949	Durango, Colo.	Vanadium Corp. of America	Yes		Salt roast
1950	Monticello, Utah	The Galigher Co. for the Atomic Energy Commission	Yes	O	Salt roast
1955			No	A	None
1955			No	B	None
1950	Uravan, Colo.	Union Carbide Nuclear Co. (formerly U. S. Vanadium Co.)	Yes	A	Salt roast for low-lime ores
					Tails
1953			Yes	B	Lime kill for high-lime ores
1951	Grand Junction, Colo.	Climax Uranium Co.	Yes		Acid conditioning—sand-slime separation—slimes salt roasted
1951	Salt Lake City, Utah	Vitro Uranium Company (formerly Vitro Chemical Company)	No		Bake for carbonaceous ores
1953	Bluewater, N. M.	The Anaconda Co. (formerly Anaconda Copper Mining Co.)	No	A	None
1955			No	B	None
1955	Shiprock, N. M.	Kerr-McGee Oil Industries, Inc.	No	A	Acid cure
1956			No	B	None
1956	Edgemont, S. D.	Mines Development, Inc.	No		None
1956	Moab, Utah	Uranium Reduction Co.	No		None
1956	Tuba City, Ariz.	Rare Metals Corp. of America	No		None
1956	Maybell, Colo.	Trace Elements Corp.	No		None
1956	La Sal, Utah	Continental Uranium Inc.	Some		None

chlorides and nitrates of approximately molar concentration, with the pH maintained between 1.0 and 1.5. The uranium ionic complex is replaced with the nitrate or chloride anion, which also restores the resin for re-use. The uranium is then precipitated from the pregnant eluting solution by neutralizing the solution with a base. Ammonia or magnesia are generally used.

Although these ion exchange techniques now employ semicontinuous or intermittent batch operations, it is anticipated that in the near future equipment will have been developed and thoroughly proved so that true countercurrent continuous ion exchange processes can be operated. This will decrease production costs, facilitate the ion exchange operation, and give more economical use of resin and eluting chemicals.

It is also anticipated that recently developed liquid-liquid solvent extraction processes for clear liquors or dilute slime pulps may soon be utilized for full-scale recovery of uranium from its ores. The most satisfactory reagents so far developed for selective uranium extraction from sulfuric acid leach liquors appear to be the highly branched chain alkyl phosphates and alkyl amines, which are carried in a cheap organic diluent such as kerosene. The uranium is then stripped from the organic solvent by an acidic or basic aqueous solution and the organic solvent returned to the extraction circuit.



The Uravan, Colo., mill of Union Carbide Nuclear Co., formerly U. S. Vanadium Co.

Table of the Western Uranium Mills and their Respective Processes,* Jan. 1, 1956 (Continued)

Leach	Liquid-Solid Separation	Uranium Recovery	Uranium Refining	Remarks
Sodium carbonate quench and percolation, followed by acid percolation for scavenging values	Leach tanks	"Yellow cake" precipitation	Reducing fusion	Values recovered from acid leach liquors by addition of excessive sodium carbonate. Alumina sludge removed and liquors sent to carbonate quench
Water quench and percolation for vanadium extraction, followed by acid percolation for uranium extraction	Leach tanks	"Green sludge" precipitation	"Green sludge" digestion and liquor purification	
Sodium carbonate quench and percolation followed by acid percolation for scavenging values	Leach tanks	"Yellow cake" precipitation	Reducing fusion	Values recovered from acid leach liquors by addition of excessive sodium carbonate. Alumina sludge removed and liquors sent to carbonate quench
Carbonate agitation	CC decantation and filtration	"Yellow cake" precipitation	Reducing fusion	Circuit O converted to circuit A in 1955
Carbonate agitation	Filtration and CC decantation	Caustic precipitation	None	Liquor regenerated with bicarbonate
Acid agitation	Sand-slime separation	R.I.P. ion exchange	None	
Water quench and percolation for vanadium extraction, followed by acid agitation for uranium extraction	Water - leach tanks, acid, sand-slime separation on calcine and CC washing in classifiers and thickeners	"Green sludge" precipitation	"Green sludge" digestion and liquor purification	Since summer of 1955 all uranium recovery being made by ion exchange columns
Acid agitation	CC decantation	↑ Ion exchange columns	None	Ion exchange columns started in 1955
Sands, acid percolation, calcine, water agitation for vanadium extraction, and acid agitation for uranium extraction	Sands, leach tanks, calcine, CC filtration	Phosphate precipitation	Caustic digestion and Reducing fusion	Changed from acid percolation of calcine to CC filtration in 1955
Acid agitation	CC decantation and filtration	Phosphate precipitation	Double caustic digestion	
Carbonate agitation autoclave	Filtration—both CC and advancing washes	Caustic precipitation	None	Uses both drum and Burt filters. Liquor regenerated with flue gas
Acid agitation	Sand-slime separation	R.I.P. ion exchange	None	
Water agitation }	Sand-slime separation and CC washing in classifiers and thickeners	Ion exchange columns	None	
Acid agitation }				
Acid agitation	Sand-slime separation	R.I.P. ion exchange	None	
Acid agitation	Sand-slime separation	R.I.P. ion exchange	None	
Acid agitation	Sand-slime separation	R.I.P. ion exchange	None	
Acid agitation	Leach tanks with auxiliary CC decantation circuit	Ammonia precipitation	None	Contracted to produce a "low grade" concentrate
Acid agitation	CC filtration	Ion exchange columns	None	Recovery to be made of leached vanadium

Abbreviations: CC—countercurrent; R.I.P.—resin-in-pulp.
* Table includes only operators which have AEC contracts for the Commission to purchase the uranium contract.
† Year of initial uranium concentrate shipment to Grand Junction or startup operations essentially completed.

There are also promising possibilities of using uranyl complexing reagents so that simpler organic compounds such as tributyl phosphate can be utilized to extract uranium from sulfuric acid leach solutions into water immiscible solvents. Besides extracting the uranium directly from the acid leach liquors, solvent extraction processes also appear attractive for removing uranium from ion exchange eluates. This will eliminate certain chemical costs incurred in neutralizing the eluates for uranium recovery and will effect an additional upgrading step that increases the ratio of uranium concentration and obtains a higher purity product.

If the problem of eliminating or recovering organic entrainment in the thick aqueous slurries (20 to 50 pct solids) can be economically solved, this should make possible one of the ultimates in liquid-liquid solvent extraction, that is, contacting the thick leach slurries directly with organic solvent for uranium extraction without requiring the intermediate steps of solids removal from the pregnant leach liquors.

Leaching uranium ore directly with a nonaqueous solvent has certain attractive features: liquid-solid separations can be accomplished with ease, and there is a possibility of finding a nonaqueous solvent and method that will extract the uranium selectively, without the high acid consumption occurring on many ores when they are given an aqueous acid leach, particularly ores of substantial lime content. However, there are still many problems to be investigated and solved in leaching ores with nonaqueous solvents, such as recovering solvent from the leached ores, and obtaining consistently good extractions on a variety of ores.

Another process in the laboratory stage of development is a modification of the char adsorption process used in the Golden Cycle Corp. mill at Victor, Colo. A uranium complexing reagent is first adsorbed on the char. The modified char is fed countercurrently through the uranium leaching circuit, adsorbing the uranium, and is then fed countercurrently through an eluting circuit in which an eluting solution removes the uranium and restores the char for re-use in the leaching circuit.

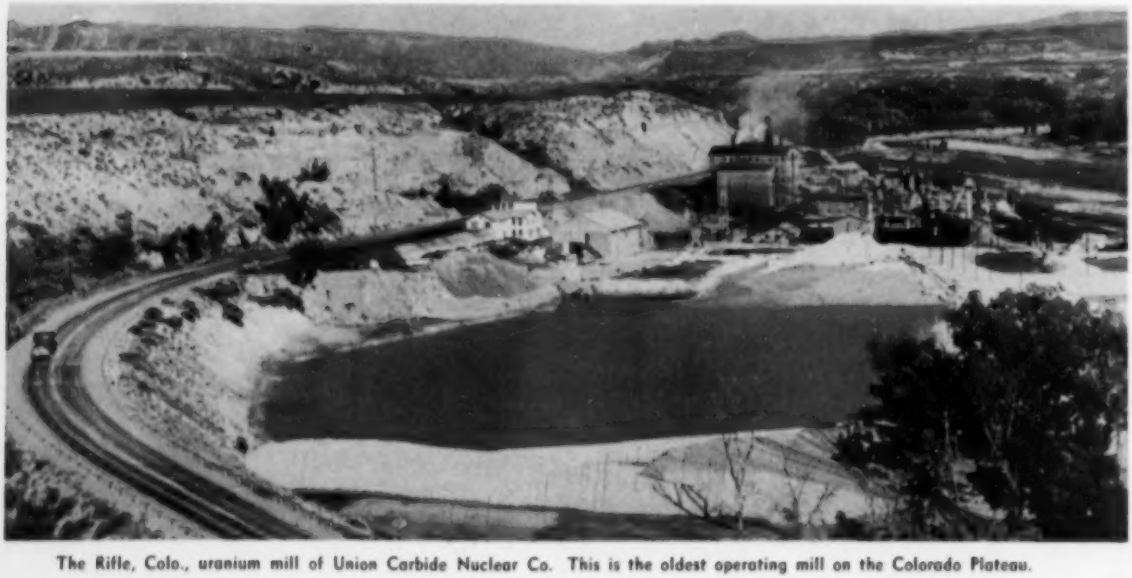
One of the newer laboratory developments for processing uranium ores is ammonium carbonate leaching. Indications are that leaching with an ammonium carbonate solution at 90 to 110 psig and 105° to 115°C will give uranium extractions on a par with sodium carbonate leaching for certain ores. Steam stripping the ammonia and carbon dioxide from the pregnant leach liquors causes the uranium to precipitate. The ammonia is recovered and recarbonated in solution for re-use. Such a process involves relatively low reagent cost, as only makeup ammonia is necessary.

Attempts to make a uranium concentrate from domestic ores by mechanical means have met with little success. Any such uranium concentrate that may be produced will undoubtedly have to go through a chemical processing stage to be suitable refinery feed; thus, unless something revolutionary develops, uranium concentrate production will always involve leaching and hydrometallurgy.

Recovery Processes

Any article covering in detail the history, development, and processes of uranium milling in the Colorado Plateau would be of serial proportions. However, uranium recovery processes now being used can be divided into six basic operations: 1) feed preparation, 2) ore pretreatment, 3) leach, 4) liquid-solid separation, 5) uranium recovery, and 6) uranium refining. Eliminating the basic operation, feed preparation, which involves crushing and grinding too fundamental to be included as a unique part of uranium ore processing, the accompanying table lists under the remaining five basic operations the applicable data for each uranium mill.

The remainder of this article, pp. 625 to 629, is supplemental to the table and presents brief explanations of the various methods used for performing each operation. Illustrations outline key operations of the flowsheets which have been utilized for uranium recovery. Where one illustration can be used to show two similar flowsheets, this is done. Differences between the similar flowsheets are shown by the blocks connected with the dotted indication line.



The Rifle, Colo., uranium mill of Union Carbide Nuclear Co. This is the oldest operating mill on the Colorado Plateau.

Briefs on Operational Methods Used in the Western Uranium Mills

Uranium Refining

Reducing Fusion: The impure or low grade uranium concentrate is mixed with a formulated flux of sodium carbonate, salt, and sawdust or fuel oil and heated, while being stirred, to about 950°C. This reduces the uranium to the black, water insoluble uranium dioxide and with the exception of nonamphoteric metals forms water soluble sodium salts of the vanadium, alumina, silica, phosphates, and other constituents of the cake. The cooled melt is then water leached, leaving a residue of black insoluble uranium dioxide.

"Green Sludge" Digestion and Liquor Purification: The green sludge is redissolved in acid, and by selective precipitation involving pH adjustments and a final neutralization with excessive sodium carbonate, the liquor is eventually purified to contain little other than uranium. Uranium is then recovered by acidifying the sodium carbonate solution, boiling off the carbon dioxide, and adding a base which quantitatively precipitates the uranium.

Caustic Digestion: The impure or low grade uranium concentrate is given a strong, hot caustic wash which does not dissolve the uranium but removes substantial amounts of phosphate and amphoteric impurities, such as alumina, silica, and vanadium, as well as dehydrating the wet concentrate. A double caustic digestion is a series of two caustic digestions.

Uranium Recovery

"Yellow Cake" Precipitation: Sodium carbonate solutions containing uranium and vanadium are neutralized with sulfuric acid to a pH of 5 to 6, and the carbon dioxide is boiled off. This quantitatively precipitates the uranium as a yellow, sodium uranyl vanadate, called *yellow cake*. Vanadium in excess of the stoichiometric amount required to precipitate the uranium remains in solution.

"Green Sludge" Precipitation: Acid leach liquors are neutralized, precipitating the uranium and vanadium along with iron, alumina, silica, and other metals and acid soluble hydrates dissolved from the ore. *Green sludges* generally contain less than 10 pct U_3O_8.

Caustic Precipitation: Uranium is precipitated as sodium polyuranates from carbonate solutions by addition of caustic in excess of that necessary to neutralize the bicarbonate ion. Precipitation is not quantitative, but this is not critical since the stripped liquor is regenerated and returned for use in the leaching circuit.

Phosphate Precipitation: By addition of a reducing reagent such as iron or aluminum, uranium in the acid liquor is reduced to the uranous state (U^{+4}) and precipitates from the acid solution as a specie of uranous phosphate. Several times the theoretical amount of phosphate should be present in the liquors for this precipitation. Unique conditions, not generally accomplished, are necessary to produce a satisfactory barren.

Ion Exchange Columns: Uranium is selectively adsorbed on anion resin in ion exchange columns as the liquor flows through the resin bed. Clear liquors are necessary to prevent plugging the bed. The uranium is removed from the resin by an acidic eluting solution, generally containing about one molar concentration of a chloride or nitrate salt with a 0.1 normal concentration of acid. The uranium is precipitated from the eluting solution by neutralization.

R.I.P. Ion Exchange: Sized, anion resin is contained in screen baskets that are moved up and down in the passing solution. This makes it possible to contact dirty liquors or dilute pulps with the resin and eliminates the need for costly production of clear liquors. The liquors should not contain any +325 mesh solids. The uranium is removed from the resin by following the uranium adsorption cycle with a uranium eluting cycle, using nitrate eluting solutions similar to those used in ion exchange columns.

Ammonia Precipitation: Actually, this is production of a *sludge* by neutralizing acid leach liquors with ammonia. The uranium grade of the sludge depends upon the amount of other constituents in the ore which are dissolved by an acid leach, so the grade of the sludge produced will vary with different ores.

Liquid-Solid Separation

Leach Tanks: Percolation leaching in filter bottom tanks is a simple and effective method for leaching calcines or crushed, high porosity ores. Washes are advanced and high grade solutions can be obtained.

Sand-Slime Separation: Sands and slimes are hydraulically separated and sent to separate circuits for washing or uranium recovery. Slimes are generally considered to be the −325 mesh fraction, although the separations may vary from this.

CC Washing and Decantation: Cyclones and rake, drag, or spiral classifiers are used to wash and decant sands when they are handled separately. Thickeners are used to wash and decant slimes or unclassified pulp.

Filtration: Recent development of the polysaccharide flocculating and filter aid reagents and techniques for their use have helped to make filtration of domestic uranium ores economically possible. Use of drum filters is coming into practice, with the following comparative ranges of filtration rates:

Material or Ore	Filter Rate, Lb Per Sq Ft Per Day	Filter Aid
Calcine	2000 to 2500	No
Limestone	1000 to 1500	Maybe
Bentonitic sandstone	500 to 1000	Yes
Slimes	100 to 300	Yes

Disk filters are used for slimes and extremely slimy materials if liquid-solid separations are made.

Leach

Water: Ore is water leached after salt roast for extraction of the water soluble sodium vanadate formed. Acid cured ore is also water leached which, in effect, becomes an acid leach of already solubilized values.

Acid: An acid leach extracts the uranium and also the acid soluble vanadium. If the mill produces a vanadium concentrate, this acid soluble vanadium is recovered. Sulfuric acid solutions are used for acid leaching, some mills utilizing amounts of hydrochloric acid which they recover from their salt roasting operations. Generally 40 to 50 lb of HCl per ton of mill feed roasted can be recovered.

Carbonate: Sodium carbonate solutions are selective for vanadium and uranium extraction. Vanadium is quickly extracted from salt roast calcine, but high temperatures and longer contact time are necessary to make a good uranium extraction. Only the vanadium chemically associated with the uranium mineralization is extracted in carbonate leaching the raw ore where prolonged contact time and high leaching temperatures are necessary to effect good uranium extractions. As carbonate leaching will extract only oxidized uranium (U^{+6}), the leach should be maintained under oxidizing conditions. Bicarbonate must be present in the leaching solution to prevent hydroxyl ion formation that would cause precipitation of the uranium.

Percolation: A salt roast calcine gives a dehydrated porous and easily filterable material through which solutions can readily percolate. Low lime sandstone ores which contain only a small amount of bentonitic slimes and clays (less than 10 pct) can also be percolated if care is taken to prevent size classification in the percolation tanks.

Agitation: Ground ore or calcine is agitated in the leaching solutions, the pulps ranging from 30 to 55 pct solids.

Ore Pretreatment

Salt Roast: −14 mesh ore is mixed with salt, 6 to 7 pct by weight, and roasted at 825° to 850°C in multiple hearth roasters. This is done to convert the vanadium to soluble sodium vanadate for vanadium leaching and recovery.

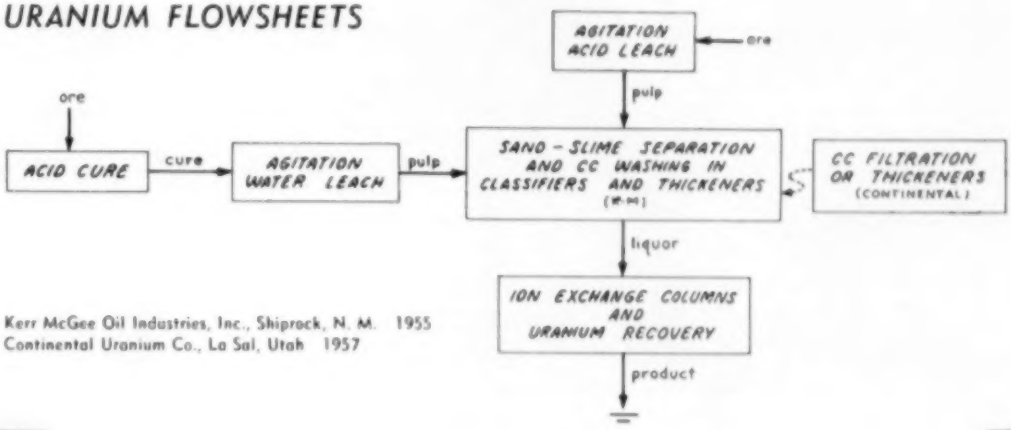
Lime Kill: Ore containing over 3 or 4 pct lime is given an initial acid leach at a pH of about 1.5, which extracts up to 80 pct of the uranium and converts the lime to calcium sulfate. This largely reduces the calcium interference in the formation of sodium vanadate in the salt roast. The lime-kill tails are subsequently salt roasted for vanadium extraction and the acid leach liquors go to ion exchange for uranium recovery.

Acid Conditioning: Ore is acid treated with plant waste acid liquors to neutralize the lime in the ore. The pH of the pulp is then readjusted to between 6 and 7 with plant waste basic liquors or ammonia before going to sand-slime separation. This process also precipitates any uranium and vanadium values left in the plant waste liquors, and this precipitate follows the slimes.

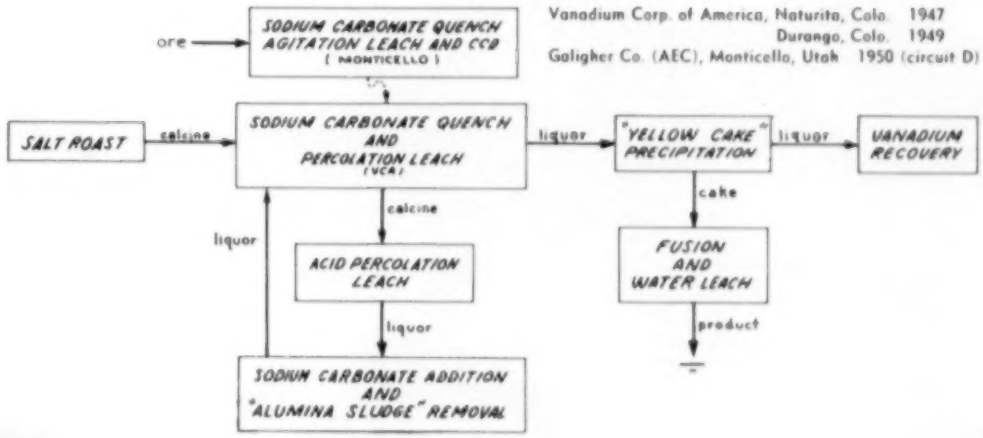
Bake: Ore is heated in multiple hearth roasters to just under incipient red heat (less than 500°C) in order to burn out carbonaceous material. A bake increases the settling and filtering characteristics of an ore severalfold.

Acid Cure: Ore is pugged with about 10 pct water and an excess of concentrated sulfuric acid. If about 300 lb of excess acid are used per ton of ore, the acid cure will solubilize the refractory vanadium minerals in the ore. The pugged mixture is allowed to cure in a pile, and if sufficient lime is present in the ore, the exothermic reaction raises the ambient temperature of the pile to 100° to 150°C, completing solubilization of uranium and vanadium values in several hours. Enough moisture must be available during the cure to allow hydration of the calcium sulfate formed.

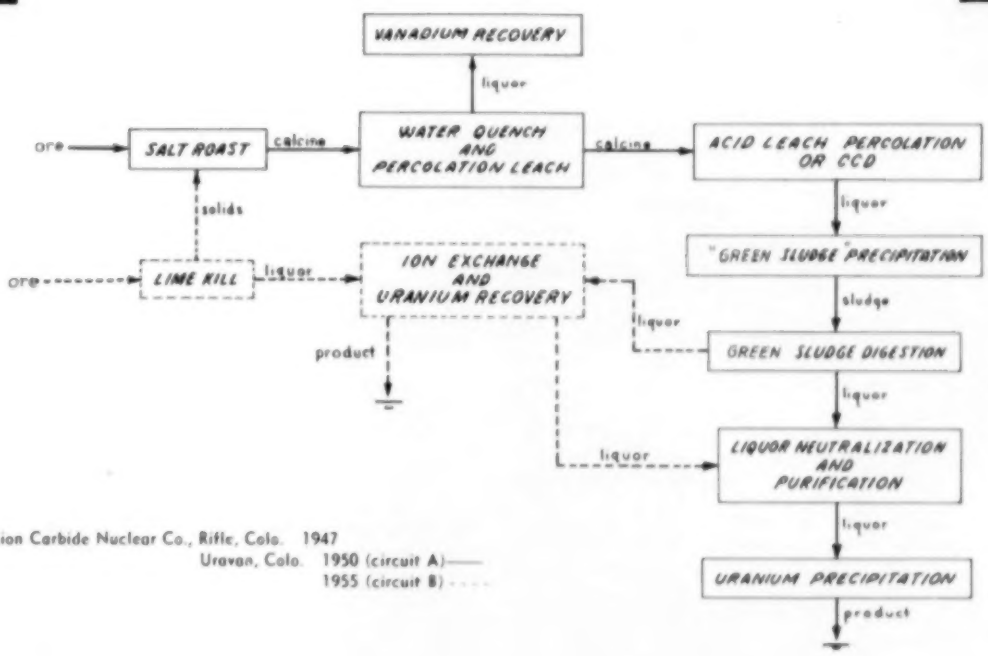
URANIUM FLOWSHEETS



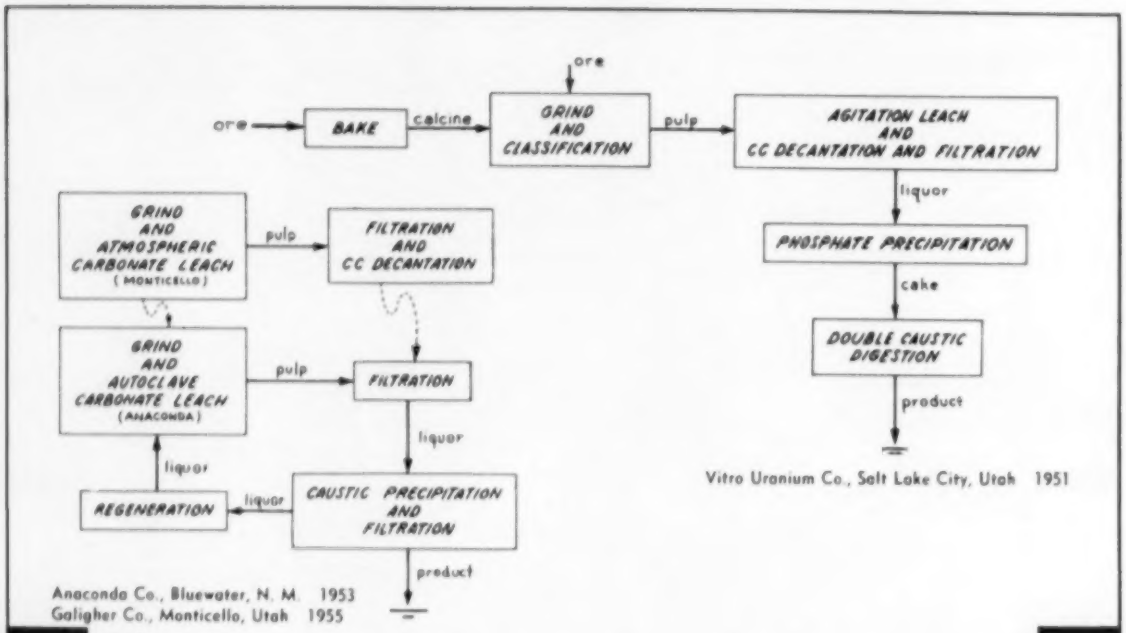
Kerr McGee Oil Industries, Inc., Shiprock, N. M. 1955
Continental Uranium Co., La Sal, Utah 1957



Vanadium Corp. of America, Naturita, Colo. 1947
Durango, Colo. 1949
Galigher Co. (AEC), Monticello, Utah 1950 (circuit D)

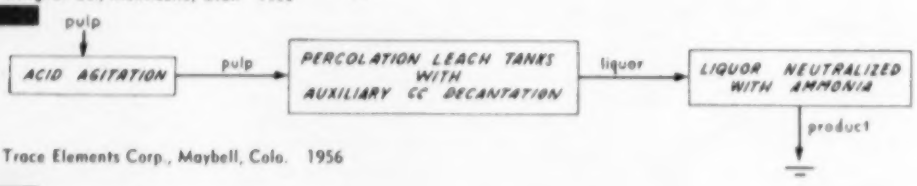


Union Carbide Nuclear Co., Rifle, Colo. 1947
Uravan, Colo. 1950 (circuit A)——
1955 (circuit B) - - - -

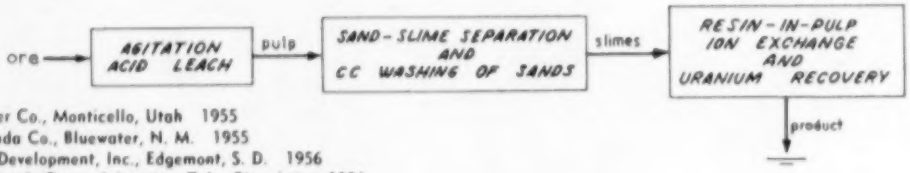


Vitro Uranium Co., Salt Lake City, Utah 1951

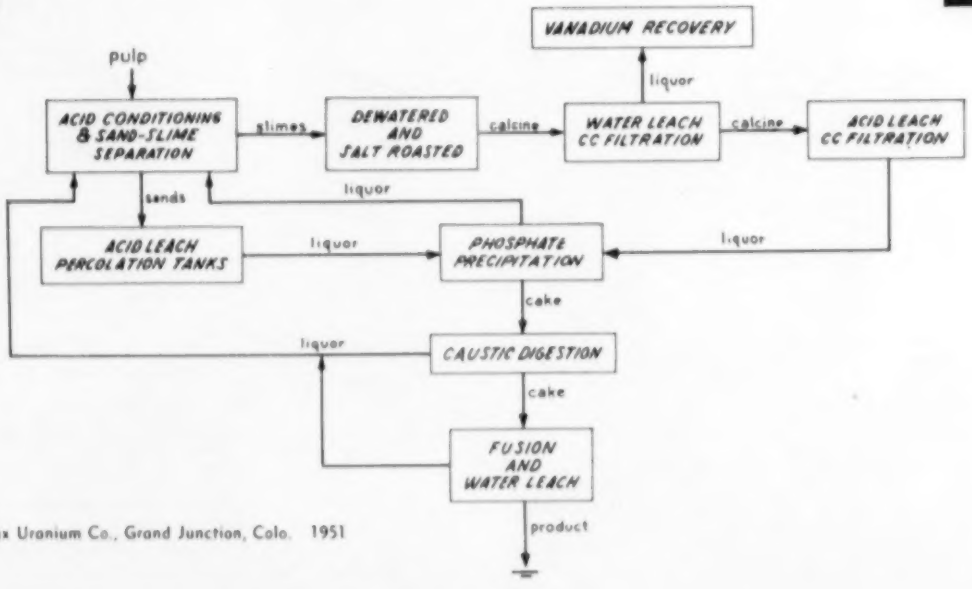
Anaconda Co., Bluewater, N. M. 1953
Gallagher Co., Monticello, Utah 1955



Trace Elements Corp., Maybell, Colo. 1956



Gallagher Co., Monticello, Utah 1955
Anaconda Co., Bluewater, N. M. 1955
Mines Development, Inc., Edgemont, S. D. 1956
Rare Metals Corp. of America, Tuba City, Ariz. 1956



Climax Uranium Co., Grand Junction, Colo. 1951

Petrologic Methods for Application to Solid Fuels of the Future

Coal is differentiated variously according to criteria of composition and texture by different systems of coal petrology. Accordingly, terminology is not uniform. Different procedures are discussed, including Thiessen's Whipple disc method and procedures suitable for study of oriented and disoriented samples of coal. Coal petrology should be applied more fully to problems of geology, mining, and technology.

by James M. Schopf

COAL petrology is the study of the lithologic composition and texture of coal and includes megascopic as well as microscopic differentiation. Coal petrography is a quantitative study, principally (but not exclusively) microscopical in nature. The distinction between coal petrologic and coal petrographic studies usually is not important, but it is important to recognize that these studies differ materially from other types of petrology that deal primarily with minerals. The petrologic entities* of coal are less clearly distinguished than most minerals and the basis of distinction is not always clearly expressed. The relation of coal petrology to geologic, mining, and technologic problems is most evident when results of coal petrologic studies can be stated quantitatively.

* Materials in coal that are identified or distinguished in coal petrology are here spoken of generally as *coal petrologic entities*. This noncommittal expression is desirable because it may include minerals and because sometimes distinctions are drawn more or less sharply between entities spoken of as the *ingredients, constituents,* and organic *components* of coal. Other classes of coal petrologic entities are macerals and phyterals.

The chemical and physical composition of coal and the determination of its *quality* and properties are continuing problems. The source of these problems lies in the heterogeneity of coal and in its almost complete insolubility in ordinary solvents at normal temperatures. The empirical and comparative character of standard chemical coal analytic values is one of the consequences resulting from heterogeneity and insolubility of coal. Nevertheless, these coal analytic methods are highly technical and diversified. Coal petrology employs a group of similar analytical methods which provide information about coal that the other methods cannot supply. The heterogeneity of coal is most clearly demonstrated by means of petrologic studies.

The properties utilized in coal petrologic studies are related to texture (size, form, and association), hardness, light reflectance, and light absorption and transmission (color). Size relations are most evident but are commonly overlooked. Coal is classed chemically as a mixture, and chemical analyses thus show the composition of the sample as a whole. Geologically coal is an organic clastic deposit, derived from diverse plant fragments and particles having a size range comparable to that of a conglomerate or breccia. The mixture of different materials that compose coal, large and small, can be realized only by microscopic study. This is because the fundamental cellular units of plants, from which coal is formed, are microscopic in size. The kinds of altered plant particles and fragments in coal have specific differences in hardness, reflectance, and color that signify differences in composition. These differences must be taken into account in evaluating the aggregate properties of coal.

RELATIVELY REACTIVE COMPONENTS		RELATIVELY INERT COMPONENTS
(1) Megascopic Anthraxylon (>1/2 mm)		(13) "Dark" Brown Matter
(2) Attrital Anthraxylon (1/2 mm to 14 μ)		(14) Granular Opaque Matter
(3) Sub-anthraxylon (14 μ to 3 μ)	Translucent Humic Degradation Matter (THDM)	(15) Amorphous Opaque Matter
(4) Humic Matter (<3 μ)		(16) Fusinized Opaque Matter (<30 μ)
(5) "Light" Brown Matter		(17) "Dark" Semi-Fusain (>30 μ)
(6) "Red" Resins		(18) Attrital (Micro) Fusain (30 μ to 1/2 mm)
(7) Spore Coats, (8) Cuticles	Cerebral Matter	(19) Megascopic Fusain (>1/2 mm)
(9) Amorphous Wax		(20) Pyritic Minerals
(10) Suberin, (11) "Yellow" Resins		(21) Clayey Minerals
(12) Fungal Matter		(22) Other Minerals

Fig. 1—General list of relatively reactive and relatively inert components in coal.

Terminology and Texture

Full discussion of terms applied by various petrologists in analysis of coal is beyond the scope of this article. For convenience the simpler types of petrologic entities that are defined without reference to lithologic occurrence or texture will be called coal *components*. Fig. 1 lists *reactive* and relatively *inert*

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The Transactions papers appearing in Mining Engineering during 1956 will subsequently appear in AIME Transactions Volume 205 and may be permanently referenced to that volume.

Fig. 2—Comparison of megascopic ingredients with list of components in coal.

components. The contrasting degree of reactivity of various coal components to oxidation, hydrogenation, etc., should not be confused with general distinctions between carbonaceous and noncarbonaceous substances.

Some of the components listed are distinguished by arbitrary size boundaries or *thresholds*. Others, such as resins and cuticles, are identified without reference to size. Although this list is not exhaustive, it includes practically all compositional or physical elements that are quantitatively identified in one form or another in the various systems of coal petrography.

It is customary to speak of the megascopic entities of coal as *ingredients* or as *banded ingredients*. A comparison of the list of megascopic ingredients and the list of coal components is presented in Fig. 2. Exclusive of mineral components, all components except megascopic anthraxylon and megascopic fusain enter into the heterogeneous composition of fine-textured or attrital coal. Varieties of attrital coal are most difficult to define precisely and their range of composition greatly concerns us. Clarain and durain, mentioned in Fig. 2, contain all the elements of attrital coal; hence their effective discrimination must be on a quantitative microscopic basis. German coal petrographers have followed this practice for a number of years, and in their studies *clarit* and *durit* have only a microcompositional connotation (Ref. 1, pp. 277–280). Neither clarain nor durain is capable of explicit definition by megascopic standards; a broad range of attrital coal, intermediate between the two extremes of composition that are more distinctive, makes it appear unwise to use clarain and durain for purposes of general megascopic comparison.

It seems appropriate, for present purposes at least, to refer to the four standard entities of Thiessen's analyses,[5] first presented in 1931, that combine criteria of texture with criteria of composition as the *constituents* of coal. Fig. 3 illustrates the relation of the components to the constituents of this standard analytic grouping. The equivalence of the megascopic ingredients, Fig. 2, and microscopic constituents, Fig. 3, can be readily observed if the columns listing them in Figs. 2 and 3 are superimposed on each other.

Stopes proposed in 1935 that the microcompositional entities in coal, analogous with minerals, be called *macerals*. During the last few years German scientists have applied a modified maceral terminology in coal petrologic studies.[1, 3, 4] None of the macerals that have been defined involve textural criteria. Fig. 4 shows the principal maceral entities in comparison with the same list of components given in previous figures.

As may be seen from the preceding charts, none of the ingredient, constituent, or maceral entities in coal, except the mineral impurities, are precisely equivalent to each other. Each of these entities involves a different component assortment. Terminology of different systems cannot be regarded as strictly synonymous.

Many writers apparently do not realize these differences exist between the different classifications. They have assumed, for example, that vitrain and anthraxylon are the same (Ref. 5, p. 46; Ref. 6, p. 266). Fig. 5 has been arranged to show the varying usages and proposals.

It is evident that coal petrographers differ greatly in their interpretation of the thickness of bands that should be assigned to vitrain. Anthraxylon, however, appears to have been identified by all according to the same size criteria after Thiessen first devised his quantitative system of coal petrography in 1931 (Ref. 7, pp. 551–555). The terms *vitrain* and *anthraxylon* usually apply to very different textural (band thickness) fractions of a coal. Differences in application of terms are illustrated in independent studies of coal from the same mine by McCabe[6] (1936) and by Thiessen and Sprunk (1932).[5] In the coal from that mine McCabe identified 22.7 pct vitrain (band thickness exceeding ½ mm) and Thiessen and Sprunk identified 70 pct anthraxylon (thickness exceeding 14 μ). A restudy of this coal by the writer, applying the same megascopic ($> ½$ mm) and microscopic ($> 14\ \mu$) standards, confirmed the results of Thiessen and Sprunk and of McCabe.

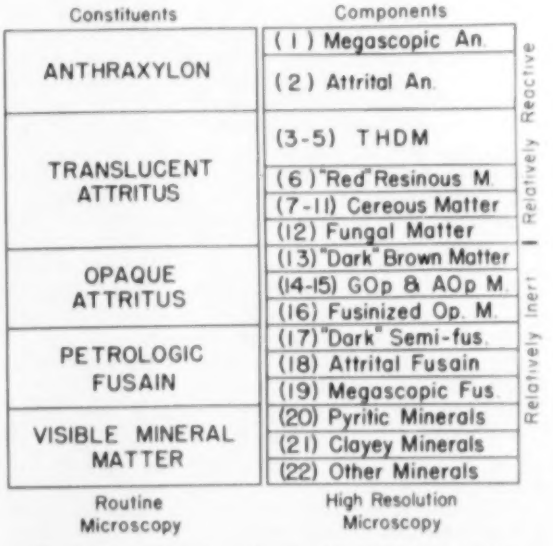

Fig. 3—Comparison of constituents with the list of components in coal.

It is not surprising that differences in textural interpretations have given rise to differences in application of coal petrologic terminology, since coal has a much more highly oriented, lineated texture than most of the rocks associated with it. Coal, like the peat from which it is derived, is an obscurely bedded deposit in which only the beds marked by detrital impurities are easily distinguished. The high degree of lineation observable in coal and allied carbonaceous deposits is largely related to compaction and compression of inherent plant materials.

The texture of coal cannot be determined without reference to orientation and, as will be brought out in a later section, this is of practical importance. Texture has not been emphasized in most coal petrologic studies, however, and frequently a clear-cut distinction between texture and composition has not been made. Terms like *anthraxylon* and *vitrain*, which have a definite textural as well as compositional connotation, have in some instances been applied to the study of disoriented coal particles where the texture could not be determined.

It is inaccurate to apply distinctions based on band width in study of disoriented coal. Some of the vitrinized strands that would normally be assigned to translucent attritus (such as subanthraxylon, Fig. 5) appear greatly exaggerated in thickness in oblique section among disoriented particles and thereby are indistinguishable from anthraxylon.

One recent study has indicated that in some samples error caused by disorientation is negligible.[10] Analyses based on granular disoriented coal were compared with analyses of oriented surfaces of the same coal before crushing. Small specimen blocks were used throughout to provide careful control. The positive error for "vitrain" (+ 25μ band width) in all nine blocks amounted to only 2.21 pct. This would seem to signify that only a very small amount of − 25μ "subvitrain" was present. It seems safe to predict that if a greater amount of "subvitrain" existed in the coal the error would be greater. The important point is that there seems to be no way of determining how great this error may be unless the exactly corresponding oriented texture has been determined.

Traverse (Ref. 11, p. 99) also has recognized the problem inherent in identifying anthraxylon in samples of disoriented coal. He expressed the belief, based on his previous study of oriented sections of a column specimen of the same coal, that his results could not be greatly affected because very little vitrinized material subsize to anthraxylon was present in the original coal. However, the actual amount of subanthraxylon was not determined.

Although the subanthraxylon content of western coals is often small, it should be recognized that the amount can vary greatly in different deposits and in different layers of the same deposit. If much coal of high subanthraxylon content is concentrated in a sample studied as disoriented granules, a considerable proportion of subanthraxylon would not be distinguishable from anthraxylon. The results thus would not be comparable with other studies.

The distinction between oriented and disoriented coal evidently is important for consistent usage of terms, and its corollary, the consistent reporting of results. Terms that have textural implication should not be applied unless pertinent size limits can be determined. The terms *vitrain* and *anthraxylon* have size limits and, for this reason, their application should be restricted to oriented specimens of coal.

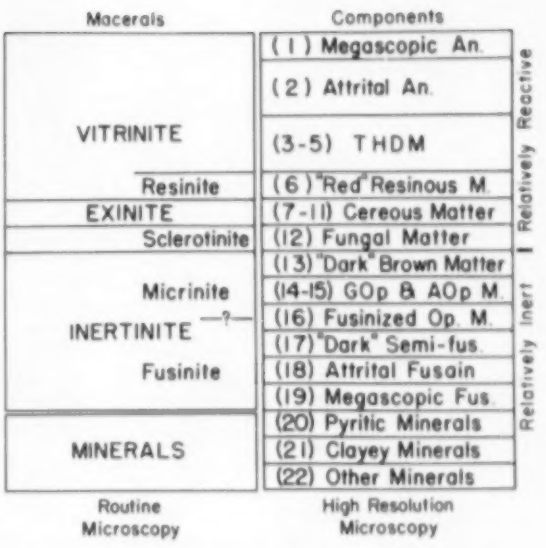

Fig. 4—Comparison of macerals with the list of components in coal.

Vitrinite, which carries no size connotation, is a suitable term for use whenever implication is *not* related to texture, and it may have its greatest value for reporting composition of granular samples in which the orientation is random.

Notes on Petrologic Procedures

In general the writer finds the thin-section method of specimen preparation preferable for much the same reasons that transmission-absorption spectrography is more useful than reflectance spectrography. Color patterns involving differential absorption and transmission of light by thin section seem to offer a more certain basis for identification of components than the largely monochrome figures observable from polished surfaces by reflected light. Rank of coal is also important in the choice of method. Some components can be identified by use of transmitted light in extremely thin sections of anthracite that contains 8 pct volatile matter, but it usually is difficult to prepare sections satisfactory for quantitative study if coal has a volatile content less than about 20 pct. However, Sprunk[11] studied several columns of Pocahontas coal, all of which had less than 20 pct volatile matter (moisture and ash free basis), by use of thin sections. The writer examined the same sections (Ref. 13, p. 215) several years later and can attest to their quality. Stach, nevertheless, has stated that coal with less than 30 pct volatile matter cannot be ground thin enough to transmit light.[6] No one questions the value of thin section methods of preparation in study of high volatile bituminous and all lower rank coal. The method yields excellent results when applied to the high moisture coals, since it demonstrates the natural condition of coal in the bed. Shrinkage and surface oxidation effects are hard to avoid if it is necessary to use the polished surface technique. High moisture lignites have to be dried and *waterproofed* to obtain polished surface preparations that are satisfactory.

Polished surfaces alone may not be fully adequate for definitive resolution of components in high rank anthracite, but resolution can be improved by sur-

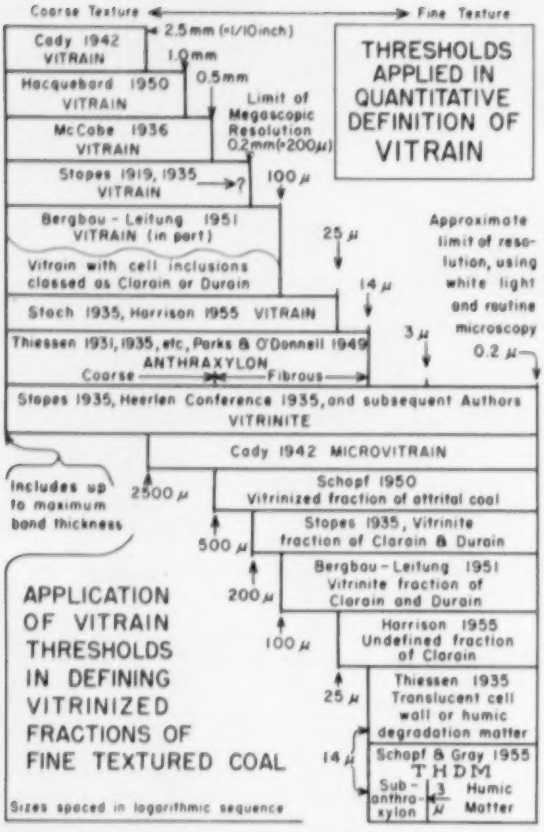
Coarse Texture
Fine Texture
Cady 1942 VITRAIN
2.5mm (1/10inch)
1.0mm
Hacquebard 1950 VITRAIN
0.5mm
Limit of Megascopic Resolution 0.2mm(=200μ)
McCabe 1936 VITRAIN
Stopes 1919, 1935 VITRAIN
100 μ
THRESHOLDS APPLIED IN QUANTITATIVE DEFINITION OF VITRAIN
Bergbau - Leitung 1951 VITRAIN (in part)
25 μ
Approximate limit of resolution, using white light and routine microscopy
0.2 μ
Vitrain with cell inclusions classed as Clarain or Durain
14 μ
Stach 1935, Harrison 1955 VITRAIN
3 μ
Thiessen 1931, 1935, etc, Parks & O'Donnell 1949 ANTHRAXYLON
Coarse
Fibrous
Stopes 1935, Heerlen Conference 1935, and subsequent Authors VITRINITE
Cady 1942 MICROVITRAIN
Includes up to maximum bond thickness
2500 μ
Schopf 1950 Vitrinized fraction of attrital coal
500 μ
Stopes 1935, Vitrinite fraction of Clarain & Durain
200 μ
Bergbau - Leitung 1951 Vitrinite fraction of Clarain and Durain
APPLICATION OF VITRAIN THRESHOLDS IN DEFINING VITRINIZED FRACTIONS OF FINE TEXTURED COAL
100 μ
Harrison 1955 Undefined fraction of Clarain
25 μ
Thiessen 1935 Translucent cell wall or humic degradation matter
14 μ
Schopf & Gray 1955
THDM
Sub-anthraxylon
3 μ
Humic Matter
Sizes spaced in logarithmic sequence

Fig. 5—Size standards used in quantitative definition of vitrain. See Refs. 2, 7, 8, 34-44.

face etching techniques. The combination of polishing and etching technique is most appropriate for coal petrographic study above the coking range of rank. Most medium volatile and high volatile bituminous coal may be prepared equally well, so far as component definition is concerned, by the thin section or by polished surface technique.

Ease of preparation frequently is given as an advantage of polished opaque preparations over thin sections. In the writer's opinion this advantage frequently is overrated. It is not easy to prepare a plane surface of coal suitable for high resolution microscopy. Mediocre thin sections are often capable of yielding diagnostic information, whereas mediocre polished surfaces are more easily subject to misinterpretation. A certain degree of lapidary artistry seems to be required to make high quality preparations, whether the objective is a really plane unscratched surface or a section uniformly thin enough to provide diagnostic information in all parts.

Although color is of much help in microdetermination of components in thin sections, publication of color photomicrographs is usually not feasible, and thus most thin-section illustrations appear superficially similar to the natural monochrome illustrations of reflected light micrographs. Recently, however, Teichmüller published an excellent set of color illustrations from which the comparison is readily observed.[14] A point of significance is that the tonal values of coal components as observed from polished surfaces and from thin sections are reversed. This can be most readily observed by reference to Table I.

The tone reversal by contrasting illumination would be of little consequence if resolution of detail were similar for all tonal values. The possibility of overestimating fusinized (opaque) materials in thin sections has long been recognized. On the other hand, a thin section provides the only critical means for determining real opacity. A recent comparative study by Parks and Teichmüller, using both methods of illumination, suggests that the elements appearing darkest in tone by either method of illumination may be overevaluated.[15] The authors show that waxy components (exinites) are consistently determined in greater quantity by use of vertical illumination, and opaque materials are usually in greater quantity by transmitted illumination. An earlier study by Parks and O'Donnell indicates that opaque matter determinations from thin sections can at least be made with relative consistency.[7] Absolute accuracy is, of course, difficult to define. Regardless of the method used, the experience of the petrologic microanalyst seems to play a larger part in the accurate determination of materials of low tonal value than it does for the other components of coal.

The point for emphasis is not that one technique of preparation or any particular method of illumination is greatly superior for the micro-study of coal. The real emphasis must always be placed on optical definition and the recognition of diagnostic features. Any method of microscopy can yield fallacious results if it is not properly applied and interpreted. Since the reflected light and transmitted light techniques show features of coal in a contrasting manner, it would seem desirable to check one method of study against the other as often as is necessary to insure general accuracy of results. Both methods of microscopy can be very effectively employed in coal petrology, and both are likely to become increasingly useful in the future.

It has been mentioned that entity determination differs in coal petrology according to various systematic procedures and that no two terms of different systems include the same quantitative range of components. These technical variations were not deliberate but arose largely because investigators followed different procedures of measurement and used different equipment. There still are no generally acknowledged analytical standards in coal petrology. One popular analytic procedure requires an integrating stage or an integrating ocular, either of which costs about $600.00, without the microscope to mount it on. Another procedure depends on the use of the Whipple disc, a graticule etched on glass, which costs $12.00. The Whipple disc, used by Thiessen in all his quantitative work, is conducive to a more specific written record of observations. Neither the Whipple disc nor the integrating devices have anything to do with the resolving power of the microscope and, given appropriate optics, systematic observations of equal refinement may be made with both. The integrating devices are somewhat cumbersome to apply to more than six components. The Whipple disc is not limited in this respect, since representation of each component is noted separately irrespective of the number.

The chief concern now and in the future is not so much with high resolution microscopy as with routine procedures that can quickly provide results of practical consequence. For this reason operation of the Whipple disc procedure in routine determinations is outlined here. Whether it is used in con-

junction with transmitted or reflected light microscopy or oriented or disoriented coal preparations, this procedure has much to recommend it as a practical method. It has been applied most commonly to studies of oriented specimens thin enough for study with transmitted light.

Table I. Comparative Appearance of Coal Entities by Transmitted and Vertical Illumination

Entities	Observation by Transmitted Illumination		Observation by Vertical Illumination
Organic	**Color of Thin Section**	**Tone in Monochrome Illustration**	**Tone of Polished Surfaces in Monochrome Illustration**
Vitrinized	Shades of red*	Moderately bright	Grayish, moderately bright
Fusinized	Black (opaque)	Very dark	Very bright
Waxy	Shades of yellow	Very bright	Very dark
Mineral			
Clayey		Nearly white (microcrystalline)	Very dark
Pyritic		Crystallites black (opaque)	White (specular)
Other			
Cracks and fissures		White (showing cement)	Black (no reflectance)
Surface scratches		Lighter in tone	Black (no reflectance)

* Lignified tissue elements in lignite having more than 40 pct moisture tend to be orange or even yellowish; cellulosic derivatives show characteristic red coloration.

Fig. 6, 1 illustrates the nature of the Whipple disc graticule with the terminology of *squares, subsquares,* and *counting row* indicated. The disc is inserted at the crossing point in the microscope eyepiece so that it appears in focus superimposed on any field viewed through the microscope. Dimensions of the field intercepted by the grid depend on the magnification of the lens system. For any combination of objective and eyepiece lenses the dimension of squares and subsquares is calibrated by use of a stage micrometer, a glass slide with an accurate microscopic ruling on it (usually 10 μ divisions).

Standard calibration used for anthraxylon determination requires magnification sufficient that one Whipple disc subsquare covers an area 14 μ on a side. By itself this calibration is no insurance of adequate resolution, but in practice it works out very satisfactorily with the usual lenses and microscopes available from four or five leading manufacturers.

Bands of vitrinized composition must exceed 14 μ in thickness to be identified and counted as anthraxylon, and the subsquare ruling serves as a convenient texture gage. The amount of anthraxylon is counted in squares and decimals of squares according to area occupied in the counting row.

The number of fields surveyed is recorded on a hand tally counter. The coal specimen is adjusted by means of the mechanical stage so that the Whipple disc appears to be successively moved, just like a yardstick, to cover a continuous path normal to the bedding across the specimen of coal as shown in Fig. 6, 2. During this transect operation the number of squares occupied by anthraxylon is accumulated mentally. At the end of the transect the total representation of anthraxylon-filled squares is recorded opposite the number of fields accumulated on the hand tally counter. The total area covered by the ribbon transect is determinable from the number of fields, according to the calibration of the Whipple disc. The part of this area occupied by anthraxylon is determinable, since each square of anthraxylon is equal to one tenth of the area of the counting row for each field.

This procedure for determining anthraxylon is both rapid and effective. For work of ordinary accuracy two such continuous transects are made across each coal section near opposite edges, with lateral offsets if there are imperfections in the preparation, as illustrated in Fig. 6, 3. Additional transects can be made if for any reason it appears that initial data are not adequate. The average value from multiple transects is accepted as a close approximation of the amount of anthraxylon present in the specimen of coal. Percentage data can be calculated for any unit of thickness desired, but these are usually not computed for units smaller than the coal represented on a thin section; frequently they are calculated for the thicker lithologic layers; sometimes the percentage calculation is only carried out for the complete bed of coal. It is most convenient to record the data as thickness (= area) units, and to prepare percentage calculations as a final operation in analysis.

Only a single constituent is determined in any one transect operation. In routine procedure, however, both opaque attritus and petrologic fusain are combined in one determination and recorded as *opaque matter*. Opaque matter is identified without reference to a size standard. An experienced analyst usually finds that lower magnification is desirable for the opaque transects than that used for determination of anthraxylon. A higher magnification and greater resolution may be needed by analysts new to this estimation procedure. Parks and O'Donnell have shown the relative accuracy that can be obtained by expert microscopists.[7] Usually the amount of opaque matter is determined in the second transect operation on any individual preparation and the total number of fields and the number of squares occupied by opaque matter recorded as for anthraxylon. Any difference in magnification, with corresponding difference in size of squares and ribbon transect area, must be specifically noted.

Fusain is determined petrographically in a third transect operation in which a size standard again is employed. The subsquare calibration used by Thies-

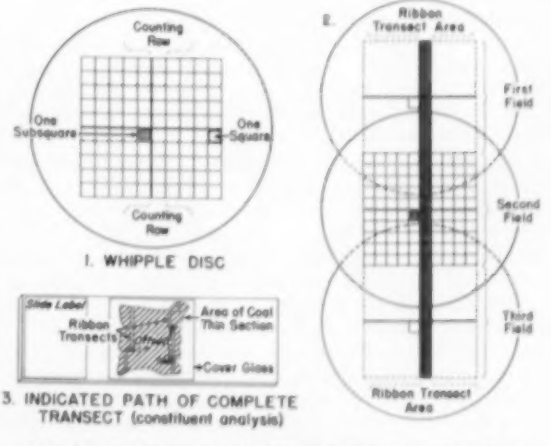

Fig. 6—Application of the Whipple disc to microanalysis of coal.

sen for fusain determination was between 38 and 39 μ. Fusinized material in lenticles thinner than this was not identified as fusain. For this work a lower magnification (32 mm) objective was used which was not parfocal and required refocusing of the microscope. In recent work at the Coal Geology Laboratory a slightly higher power 25 mm objective has been used which is more nearly parfocal with other lenses on the microscopes. At this magnification the subsquare calibration equals about 30 μ. A 30 μ size standard, rather than 39 μ, results in determination of slightly more fusain than would be determined by Thiessen's procedure. The differences, however, do not appear to be significant because fusain lenticles between 30 and 39 μ thick make up a very small proportion of the coal.

It has been remarked that fusain is the only petrologic entity for which terminology agrees between the different systems. The writer considers this correspondence more apparent than real. Perhaps discrepancies have not been as evident because fusain forms a minor part of most coal deposits. The method of determination, however, influences quantitative results for fusain just as it does for other ingredients or constituents. Fusain determined by the procedure outlined above, which includes both megascopic and attrital fusain, should be distinguished as *petrologic fusain*.

Opaque attritus is specifically determined by subtracting the amount of petrologic fusain from the amount of total opaque matter. Ordinarily no further differentiation of opaque attritus is attempted, but it is known to be composed of three fairly distinct varieties of material: 1) granular opaque matter,[16] 2) fusinized opaque matter,[10] and 3) amorphous (solid) opaque and brown matter (Ref. 9, pp. 24-27). Fusinized opaque matter consists of cell wall fragments too small for determination as petrologic fusain ($<30\mu$). The brown matter referred to is that given as *dark* brown matter in Fig. 1. A more complete discussion of the relation of opaque matter and fusain has been given previously (Ref. 13, pp. 220-22).

Translucent attritus is the most diversified and variable in composition of any of the coal constituents. Except in high resolution microscopy, determination of the components of translucent attritus is not attempted, the amount of translucent attritus (TAt) being determined by difference. Usually this is done in the final calculation in which the percentage of anthraxylon (An) plus the percentage of opaque matter (Op) is subtracted from 100 pct ($TAt = 100 - [An + Op]$). Sometimes it is more convenient to use constituent thicknesses as a basis for calculation instead of constituent percentages, resulting in an average thickness rather than a percentage of translucent attritus.

For commercial coals of normal low-ash content three transect operations generally provide adequate data for comparison. If much mineral matter is visible, however, a separate transect operation is advisable for its direct determination. If mineral matter is not directly determined it will contribute to the total translucent attritus.

All data obtained by this system of transect analysis are presented in terms of area (proportional to volume). Owing to the substantial difference in density of mineral components and organic constituents, a relatively small mineral area can contribute significantly in terms of weight percent. If visible mineral matter is directly determined it can be grouped with the other visible impurities in a coal bed and amounts of the four petrologic constituents discussed above can be recalculated on a visually pure basis.

General properties of the four organic constituents determined by this method are summarized in Table II.

Future Applications of Coal Petrology

Petrologic procedures are capable of almost infinite variation and are adaptable to many purposes. The routine procedures can provide a standard basis for comparison, but because of their general application they are often not the most appropriate for solving particular problems. Some possibilities of different procedures are indicated below:

1) Megascopic evaluation of the petrologic features in coal outcrop, mine, or stockpile.

2) Study of the lithologic composition and texture using the stereoscopic binocular or ore dressing microscope.

3) Study of lithologic entities in granular coal samples using the stereoscopic binocular microscope.

4) Study of briquetted coal powder samples using polished surface procedures with incident or vertical reflected light.

5) Study of briquetted coal powder samples using thin section procedure with transmitted light.

6) Study of oriented sections according to standard Whipple disc or integrating procedures, using reflected or transmitted illumination, or both.

7) High resolution microscopy (determination of components) using plane or polarized light, oil immersion, and either transmitted or reflected illumination (polished thin sections).

8) Quantitative reflectance determinations (Berek microphotometer).

9) Microhardness studies of components in oriented specimens.

10) Electron microscopy of selected coal components.

Usually these petrologic procedures are of greatest significance when they can be combined with other methods of analysis or testing. Correlation of petrologic results with test results indicates the relationship of petrologic entities with their behavior under experimental conditions. Thiessen and Sprunk showed, for example, that during carbonization the first changes appeared in anthraxylon.[17] Careful consideration must be devoted to effective sampling, commonly a most critical part of the procedure. The nature of samples will serve to determine whether methods appropriate for oriented or for disoriented coal should be used.

Specific micro-reflectance tests[18,19] in which, essentially, index of refraction is measured for entities no more than a few microns in diameter, have been of much theoretical interest in recent years. These relatively precise studies provide the most convincing demonstration of the physical and chemical heterogeneity of the microstructure of coal and serve to confirm and supplement other kinds of petrologic observations. Microhardness tests can be made similarly specific (but not necessarily as precise) for a

Table II. Characteristics of Coal Constituents

	Relatively Reactive Coal Constituents		Relatively Inert Coal Constituents	
	Anthraxylon	**Translucent Attritus**	**Opaque Attritus**	**Fusain**
Metamorphic	Properties of anthraxylon vary according to stage of metamorphism (rank).	Properties of translucent attritus vary a little less than anthraxylon (according to content of waxy matter) in coals of lower rank (>25 pct volatile matter); they probably are similar to anthraxylon in coals of higher rank.	Properties of opaque attritus probably show slight variation according to stage of metamorphism.	Properties of fusain show little variation depending on stage of metamorphism.
Swelling and Agglutinating	In coal of bituminous rank anthraxylon is material to which swelling and agglutinating properties are principally due.	In coals of high volatile bituminous rank translucent attritus contributes moderately to swelling and agglutinating properties, depending on the concentration of subanthraxylon and humic matter. In low volatile bituminous coal it probably contributes to a greater extent.	Probably opaque attritus contributes little or nothing to swelling or agglutinating properties.	Fusain does not contribute to swelling or agglutinating properties, although in low or even moderate concentrations it may add some strength to coke as an inert material, provided that other constituents have sufficient agglutinating power.
Reactivity	Anthraxylon is highly reactive and more susceptible to oxidation than other components of low and medium rank coal.	All components of translucent attritus are strongly reactive.	Opaque attritus is relatively inert to oxidation—much more than translucent attritus and possibly somewhat less than fusain.	Fusain is highly inert and least reactive of any coal constituent to oxidation.
Hydrogenation	Anthraxylon can be entirely liquified by hydrogenation in coals of low and medium rank.	Translucent attritus can be entirely liquified by hydrogenation in coal of low and medium rank.	Opaque attritus contributes materially to the nonliquified residue on hydrogenation.	Fusain cannot be liquified appreciably by hydrogenation.
Gas	Anthraxylon yields a moderate to large amount of gas on carbonization.	Translucent attritus yields more gas than anthraxylon on carbonization, depending on concentration of waxy matter.	The lower volatile content of coals with large amounts of opaque attritus suggests that little gas is yielded on carbonization.	Fusain yields a negligible amount of gas on carbonization. Due to its low content of volatile matter, fusain may be used to enhance the smokeless quality of briquetted fuel.
Tendency to Segregate	Megascopic anthraxylon (vitrain) is moderately friable and can generally be concentrated by preparation procedures that separate a low to medium gravity fraction. It tends to be more abundant in natural coal screenings.	Ordinarily translucent attritus cannot be separated as a pure constituent from common banded coal. It may be a dominant constituent of certain types of bright luster attrital coal that can be separately concentrated.	Opaque attritus cannot be separated as a pure constituent. It may be present in relatively high concentrations and materially contribute to the toughness and dull lustre of attrital coal. It may be concentrated in association with some translucent materials.	Megascopic fusain is extremely friable and easily separated. Attrital fusain is not separable in appreciable amounts.
Ash	Anthraxylon is generally lowest in ash content of any separable constituent.	In many coals translucent attritus is associated with higher inherent ash content than anthraxylon and a somewhat lower ash content than opaque attritus.	In many coals, opaque attritus is associated with a somewhat higher inherent ash content than translucent attritus.	Fusain is extremely variable in its association with mineral matter. Mineralized fusain is classed as refuse.

better appreciation of the physical character of the components. The electron microscope can have a similar application to coal petrography.

The most important principle in application of coal petrology involves dynamic appreciation of the heterogeneity of coal. From its original synthesis as organic substances in living plants to its final transformation to CO_2 and water, the materials of coal are subject to change, and changes take place at varying rates for different components. This is just as true of the response of components to metamorphic alteration as it is of responses during the various industrial processes. The relatively reactive and relatively inert components of coal differ from each other most in their rate of change during both geologic processes and chemical utilization.

Geologic Applications: For most geologic purposes variation in texture and composition relative to position in the coal bed are important. Oriented specimens are the basis for these studies. The common method of presenting results for geologic purposes is the coal bed petrographic profile, such as those used by Thiessen (see Refs. 2 and 9). Although identification of plant microfossils complements certain objectives of coal petrology it is not considered here because plant microfossils are properly studied as one of several complementary branches of paleontology of coal measures. The following list suggests the variety of petrologic applications that have particular reference to geology:

1) The kinds of plant parts, such as bark, wood, and roots, contributing to coal deposits.

2) Paleoecologic conditions of plant growth affecting deposition of coal beds.

3) Microbiology of organic accumulations and its relationship to diagenetic processes that have affected particular deposits.

4) The post-diagenetic history of coal deposits which may yield indications of maximum overburden, tangential pressure, and temperature.

5) Mineral association, including paragenesis and type of mineralization, and the effective geologic causes of mineralization.

6) Correlation of types of coal with concentrations of minor elements and explanation of minor element anomalies.

7) Texture of coal layers and its uniformity or range of variation in particular deposits.

8) Trends of variation in ingredient composition.

9) Trends of variation caused by tectonism—principally rank—and evaluation of chemical analyses as geologic indicators of metamorphism.

10) Correlation of coal beds and correlation of benches or layers within coal beds.

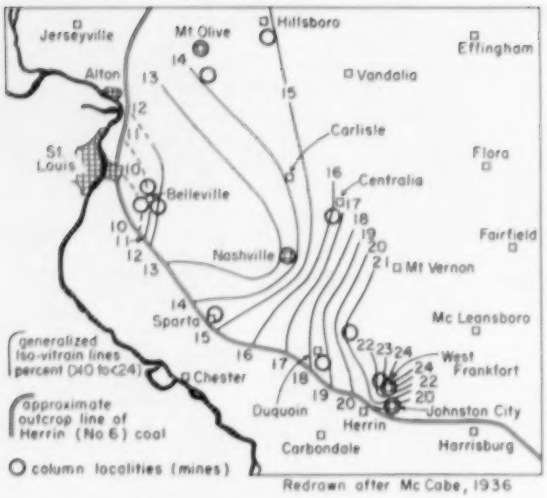

Fig. 7—Map of vitrain distribution (bands > ½ mm), Herrin (No. 6) coal bed, southern Illinois.

11) Coal type, its relation to rank, and grade classification.

12) Variations in coal as an indication of suitability of coal deposits for utilization.

Geologic interest in coal involves several aspects of coal origin. For more than a hundred years the origin of coal was controversial,[26] and a tendency existed to dogmatically explain the origin of all coal deposits according to one narrow view or another. A more sound and liberal attitude was later expressed by White.[27, 28] It is evident now that coal deposits differ greatly in their manner of formation and that the causes for these differences are determinable and have an influence on utilization of the coal. These causes also have bearing on regional geologic interpretation of coal measures. Owing to its origin from plant materials, coal is very sensitive to pressure and temperature. Plant products in a peat deposit begin to undergo metamorphic alteration when they are sufficiently consolidated to form coal.

It is generally agreed that coal having much thick vitrain has been accumulated in swampy wooded morasses where the organic material grew essentially in place. Some attrital coal is derived from rootlets that are in their place of growth, but other attrital material consists of small particles carried from a distance. In general, the finer and more uniform coal is in texture, the more likely it is to include transported materials.[29] Nonbanded coals, which have been defined as having less than 5 pct anthraxylon,[7] usually are composed entirely of transported material. The bulk of the organic particles in nonbanded coals are all less than 14 μ thick. This degree of size sorting indicates that the organic materials were pond accumulated from transported fragments.

The abundance of any one petrologic entity in coal can be mapped if data can be collected from a sufficient number of coal sections. This is best illustrated by the vitrain map published by McCabe in 1936 covering much of the southern Illinois coal field, Fig. 7. It is interesting to note that the location of the column of coal from the new Orient mine at West Frankfort, which was determined to have an exceptionally high anthraxylon content (70 pct[5]) is at the point of greatest vitrain concentration found by McCabe. Mines in this area provide the Illinois coal used for blending to make metallurgical coke.[30] The vitrain and anthraxylon relationship probably is significant.

There are so many ramifications of coal petrology which can be combined with general or specific geogolic studies that not all can be discussed. Texture trends can be mapped and may have implication as to the original area of coal occurrence and coal basins. These trends also are significant economically, as they indicate a range of physical features affecting potential utilization of the coal.

A geological consideration also important for mining is correlation of coal beds. Wagner was able to establish evidence for bed correlation in the western middle anthracite field of Pennsylvania by determining the profile distribution of combined vitrain and bright luster attrital coal.[31] Hacquebard[32] and Maurenbrecher[27] have made extensive studies of the distribution of ingredients in coal beds in Holland for purposes of detailed correlation. More recently Hacquebard has extended these studies to the coal fields of Nova Scotia.[33]

Mining Applications: A number of petrologic applications have been set down that may be of special interest in mining and beneficiation of coal. Some of these items overlap those previously listed pertaining to geology, and some might be included equally well under technologic applications. Perhaps the significant conclusion is that coal petrologic information, once obtained, can be applied for several purposes. While the occasion for a particular study may have a narrowly defined purpose, other useful information is likely to be developed without much additional work:

1) Coal type, as signified by natural associations of components; most effectively studied by means of *oriented* specimens (O).

2) Impurities, including their nature and occurrence, and their relation to mining and washing plant operations; most effectively studied by means of both *oriented* and *disoriented* coal preparations (O, and D).

3) Kinds and amounts of coal components associated with mine and washery refuse; O, and D.

4) Continuity of coal bed layers in the mine area; O.

5) Crushing strength, hardness, and friability of petrologic types of coal; O, and D.

6) Density characteristics of coal types and associated impurities; O, and D.

7) Relation of ingredients and macerals to the cleat system and its influence on mining and preparation of coal; O, and D.

8) Normal amount of maceral segregation occurring in mining and preparation of coal; D.

9) Normal amount of maceral segregation occurring in loading and shipment of coal; D.

10) Effect of different mining and preparation methods on maceral segregation; D.

11) Composition of coal fractions having special utilization properties; D.

12) Associations of minor elements with coal constituents and macerals; O, and D.

13) Composition of coal to determine feasibility of selective mining; O.

14) Kinds of macerals and associated materials that might be recovered from mine and washery refuse; D.

15) Coal characteristics that affect relative value of mining property. It will be understood that in evaluation of a mining property all pertinent information should be taken into account. Even in the absence of test data complementing petrographic information, petrology is useful in placing a relative evaluation on coal.

The effects of segregation have been emphasized in this list of possible applications of coal petrology to mining. Segregation, or selective concentration, is largely the result of physical differences in coal ingredients. Important physical differences of ingredients are a result of differences in jointing (cleating) and differences in texture. Fine texture limits segregation because of the more intimate association of heterogeneous elements in the coal. In general, the effect of cleating supplements physical differences between coal ingredients with regard to segregation. Cleating is most evident and most closely spaced in vitrain and is nearly as pronounced in attrital coal with high anthraxylon content. Cleat is more poorly developed in dull luster attrital coal, and it does not extend across bands or lenses of fusain. Segregation is not as pronounced in a coal, such as lignite, in which cleat is absent.

Coal beds vary in tendencies toward segregation of ingredients. Segregation tendencies may be more or less individual for each mine area; relatively uniform tendencies of segregation may extend through a series of mines; or segregation may follow systematic trends as previously suggested in discussion of geologic applications.

Appropriate mining practices can either promote or inhibit effects of segregation but, in ordinary processes of mining and preparing coal, selective concentrations and physical losses of coal ingredients occur. The petrologic composition of coal as it exists in the bed usually changes as the coal passes to the tipple and through the preparation plant. Thus prepared sizes of coal differ from each other in petrologic composition and from the coal as it exists undisturbed in its original occurrence. Unfortunately specific information usually is lacking concerning the magnitude of these changes, and often it cannot be stated whether they are insignificant or, under certain circumstances, may become very important.

Although natural petrologic variations in coal are likely to be gradational, slight changes in composition, owing to segregation or any other cause, may have a large effect in certain complex industrial applications. In carbonization, for example, the agglutinating or swelling fraction of the coal (principally the anthraxylon) will stand dilution by inert organic matter and impurities without noteworthy loss of strength up to a certain *saturation point*. In fact, within the permissible range, addition of inert materials may increase the bulk strength of coke, as in some of the splinty Appalachian coals. If the *saturation point* is exceeded, however, owing to reduced amount of the agglutinating constituent, a disproportionate change in coke strength occurs. If free burning is of greater interest than coking properties, the concentration of agglutinating materials can cause a striking reverse effect.

The properties of anthraxylon that are related to carbonization depend on rank to a considerable degree, as noted in Table II. As rank varies, effects of anthraxylon concentration also vary, and these effects cannot be generalized from one coal field to another; they may not even hold uniformly through one coal district. However, for coal from a specific mine the properties related to anthraxylon concentration can be determined. This information has value for operators supplying coal to the coking industry; it is equally valuable for industrial users whenever coking properties are important.

Lack of American case history information limits specific discussion of mining applications. Kühlwein and Hoffman,[29] who discuss petrologic applications to the German coal industry, cite numerous works dealing with mining and utilization of German coals. A promising petrologic method utilizing the particle-count procedure suitable for study of disoriented samples of coal has been developed by Parks[30] but has not been applied extensively enough for a full demonstration of its value in distinguishing variations in commercial coal.

There is little question that the mining applications of coal petrology will continue to be developed in the future. Most of the present information about variation in coal is based on chemical analyses having a very indirect relationship to the physical composition of coal as revealed by coal petrology. Knowledge of the petrologic composition of coal, as it is customarily prepared for shipment, is largely lacking, so that it is difficult to evaluate the effects of segregation in practice. Knowledge of composition and texture of coal in the bed provides, of course, an indication of the likelihood that segregation effects will be important in that coal bed. As such indications will probably be inadequate for future needs, it will be necessary to study carefully taken samples, using procedures appropriate to the study of disoriented coal, such as those of Parks or of German coal petrographers.

Technologic Applications

Possible technologic applications for coal petrology are many and varied. The list below is not comprehensive and these items should only be taken as suggestions. Some of these applications involve petrologic determination of:

1) Characteristics of the ideal coal for an industrial use.

2) Characteristics of prepared coals available for use by an established industry.

3) Segregation tendencies in normal shipments of coal.

4) Segregation tendencies in preparation processes at an established plant.

5) Characteristics of segregated fractions of the coals that are accessible for use.

6) Behavior of components in combustion, carbonization, hydrogenation, etc.

7) Characteristics of acceptable coal mixtures and maintenance of uniformity in blended coal.

8) Factors influencing improved operation through modification of blends.

9) Contribution of particular components to fly ash and coal refuse.

10) Associations of components with minor elements that might be usefully recovered.

11) Distribution of binder in briquettes.

12) Characteristics of coke and of changes affecting coal components during carbonization.

13) Specific surface properties of coal ingredients.

14) Nature and occurrence of minerals in coal, including their relation to slag and clinker formation.

Nearly all the possible technologic applications of coal petrology depend on effective study of disoriented samples. Such samples are, in fact, segregates from the natural textural varieties and types of coal. The basic objective in preparing coal for an industrial use is to minimize effects of the natural heterogeneity of coal so that a uniform heterogeneity is achieved for plant operation. Some processes and some types of coal-using equipment are more tolerant of variation in composition than others. Some combustion plants are supposed to be insensitive to the kinds of coal burned; this may be entirely true so far as the actual combustion process is concerned. The physical condition of the coal, however, always is a matter of cost consideration, and proper equipment must be provided for handling it. Since the petrologic composition and the nature of impurities govern the physical condition of delivered coal, information about these characteristics contributes to efficient operation.

Considerable study may be worthwhile for the purpose of defining the coal of optimum character for use with a certain type of equipment or for a particular process. Usually the practical selection of coal is limited, but it is still pertinent to consider how fractions of available coals might best be combined for optimum results.

From a petrologic standpoint, many coals in industrial use are poorly characterized. Chemical analytic data are available, but these fail to cover important physical properties. It is entirely possible to obtain very similar chemical results from coal mixtures of different petrologic character that have different physical and different *utilization* properties. Although the chemical analyses of ingredients differ (Ref. 6, p. 291), chemical data are difficult to interpret in relation to petrologic composition. Petrologic and physical composition cannot be reconstructed on the basis of chemical data alone. *Volatile matter*, *fixed carbon*, and *ash* are not substances actually present in coal. Definite information about entities that have a physical existence will aid in explaining how processes are acting on and reacting with the coal.

Some of the most important studies of the effects of coal petrology on industrial processes have been directed toward carbonization and hydrogenation uses. In this country Sprunk's studies in particular have been illuminating.[6] In recent years outstanding contributions to the German steel industry have been derived from the control of coal for carbonization blending at the laboratory headed by Mackowsky in Essen. The recent monograph on microscopical evaluation of coke by Abramski and Mackowsky is of outstanding value.[6a] Even the study of fly ash and atmospheric polution problems relate to the petrology of coal used in industrial processes as shown by Mackowsky in a substantial article on the microscopy of fly ash.[6b] Since many industrial users consume coal in such quantity that any minor improvement in operational efficiency results in a substantial saving, these possible applications of coal petrology should be worthy of consideration.

Conclusion

This article has indicated differences between entities commonly treated in coal petrology. The distinction between the terms *vitrain*, *anthraxylon*, and *vitrinite* has been emphasized. These terms apply to material that is similar in composition, but the terms *vitrain* and *anthraxylon* apply to bands having definite size limits and should be restricted to oriented specimens where measurements perpendicular to the bands can be made. Bands in disoriented coal cannot be accurately measured because of lack of orientation; the term *vitrinite* is recommended for disoriented specimens. The Whipple disc procedure has been discussed and compared with other procedures to illustrate the latitude of methods that can be employed for particular purposes. Principal emphasis in detailed coal petrology must be on the critical resolution of components that differ in composition and texture.

Procedures and applications of coal petrology that can be used for geological, mining, and industrial purposes have been discussed. Requirements of coal petrology in these fields differ greatly. Whereas geologic applications depend almost exclusively on study of oriented coal specimens, industrial applications depend largely on analysis of disoriented samples of coal.

The relations of texture and orientation to petrologic composition should receive more attention in the future. At present some fairly stabilized procedures are available for expressing the petrologic composition of oriented and disoriented coal samples, but there are no generally acknowledged standards for petrologic analysis of coal. Reference standards for analysis of both types of material are desirable; the terminology of coal petrology will be difficult to interpret until such standards are established.

In view of their potential value in defining and solving practical problems, petrologic studies will probably be extended. Coal is an indispensable raw material for the expanding carbo-chemical industries. Petrologic studies can assist in outlining usable coal reserves, in blending coal for carbonization, and in study of metallurgical coke. No other method serves to determine the amount of relatively reactive materials in coal that can be liquified in hydrogenation. Coking and free-burning qualities of coal are related to petrologic composition, and in recent years interest in composition of coal ash and association of coal with minor amounts of scarce metallic elements has been increasing. Reserves of proved value that are established in industrial uses are being depleted, and coal of somewhat different character is now being developed for these uses. The coal industry is in a transitional period in which competitive efficiency is necessary. Coal petrology is likely to find wider application in the immediate future, since it contributes to more efficient use of the nation's ample reserves of excellent coal.

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Ultrasonic Desliming and Upgrading of Ores

Experiments show that ores such as tungsten and tin, which slime excessively, can be deslimed and upgraded by ultrasonics. The method proposed depends primarily upon the stratifying and peptizing action caused when high frequency sound waves are propagated upward through ore pulp in a cylinder tube. Stratifying and peptizing are somewhat hindered by the accumulating action, which embodies additional effects of reflection and refraction.

by S. C. Sun and D. R. Mitchell

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ULTRASONICS can be used to deslime and upgrade ores, such as tungsten and tin, which slime excessively with high losses of value in the tailing and are difficult to deslime with conventional methods. Experimental work has been performed with a test-tube size ultrasonic classifier. Larger equip-

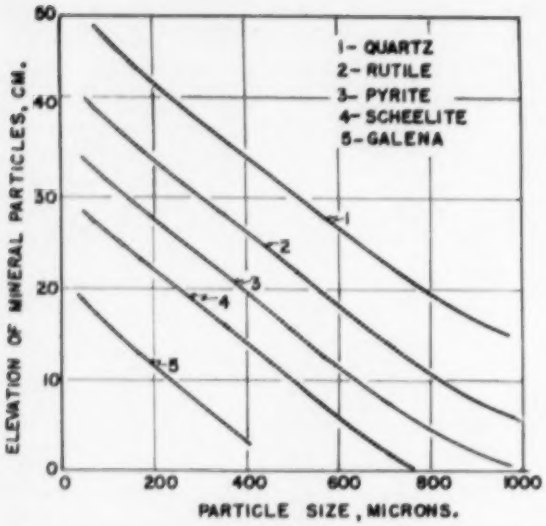

Fig. 1—Effect of particle size on the ultrasonic elevation of mineral particles in water, tested in a glass tube of 2.43 cm ID and with an acoustical pressure of 3.8 x 10^5 dynes per cm^2 below the bottom of the glass tube.

ment and further testing would be necessary to ascertain the applicability and economics of this method.

When high frequency sound waves are propagated upward through the bottom of a cylindrical tube containing an ore pulp, the mineral particles are subjected to the peptizing action of cavitation, to the stratifying action of the progressive waves, and also to the accumulating action of the standing waves. All actions originate from the radiation pressure[1, 2] of the sound waves. The accumulating action, however, embodies additional effects of reflection and refraction. The proposed method of ultrasonic desliming depends primarily upon the stratifying and peptizing actions and is somewhat hindered by the accumulating action.

The data of Figs. 1 to 3 indicate that in a vertical pulp column the stratifying action of ultrasonic waves is capable of keeping the fine-light particles at the top, the coarse-heavy particles on the bottom, and the coarse-light and fine-heavy particles in the middle. The slime or the fine-light particles in the upper strata can now be swept off by the radial flow of the wash water, and the remainder of the particles in the lower strata can be removed by a vacuum system, as shown in Figs. 5a and 5b.

This scheme of desliming is further aided by the peptizing action of the ultrasonic waves. During the investigation it was found that ultrasonic waves were able to dislodge the adhering soft gangue particles from mineral surfaces and to disintegrate the soft particles into fine sizes. This increased the amount of soft gangue materials in the upper strata for subsequent removal. The phenomenon of peptizing action is not new. Gaines[3] demonstrated that ultrasonic waves are effective in polishing and eroding surfaces of metallic nickel and glass. Sollener[4] reported that solids of moderate cohesion, such as gypsum, steatite, hematite, sulfur, graphite, asbestos, glass fiber, and gel-like precipitates, can be peptized into semicolloidal and colloidal sizes in water by ultrasonics.

The accumulating action of the stationary waves is tentatively considered slightly harmful to desliming. In a series of tests it was observed that accumulation of mineral particles at the nodes or antinodes, a phenomenon similar to Kundt's dust figures,[5] was highly pronounced only at high but not at low sonic energies. Coagulation of mineral particles, which usually accompanies accumulation,[7-9] was minimized partly by use of dispersing agents in conjunction with high pulp dilutions, partly by the vehement movement of the liquid, and partly by the peptizing action of progressive waves. Compared with the important role played by the stratifying and peptizing actions, the influence exerted by accumulating action on desliming is insignificant.

Ultrasonic Stratification of Mineral Particles in Water: The peptizing[3, 4] and accumulating[7-9] actions of ultrasonics have often been studied and need no explanations. In contrast, the stratifying action is new and had to be experimentally ascertained. Before each test was started, a glass tube 120 cm long was filled with water to the 75-cm mark. Then 0.1 to 0.3 g of mineral particles were added and allowed to settle to the bottom. The bottom of the glass tube was placed 7 cm above the bowl surface of a hypersonic transducer and subjected to a predetermined magnitude of acoustical pressure. At the end of 3 min, the elevation or the vertical distance between the bottom of the glass tube and the position of the highest rising particles was measured. This was

Table I. Reclamation of Wolframite from the —200 Mesh Slime Tailing of a Molybdenum Ore by Ultrasonic Desliming and Upgrading*

Test No.	Stage of Ultrasonic Desliming and Upgrading	Mill Refuse (—200 Mesh) Weight, G	Mill Refuse (—200 Mesh) —400 Mesh Slime, Pct	Pulp Dilution	Amount of Wash Water, CC	Length of Glass Tube, CM	Acoustical Pressure** 10^5 x Dynes Per CM^2	Product (Underflow) Weight, Pct	Product (Underflow) Grade WO_3, Pct	Product (Underflow) —400 Mesh Slime, Pct	WO_3 in Overflow, Pct	WO_3 Recovery, Pct	Removal of —400 Mesh Slime, Pct
39	Feed	16.6	38.6					100.0	1.45	38.6		100.0	0.0
	Rougher	16.6	38.6	9	800	8.4	2.5	4.8	25.26	0.0	0.25	83.5	100.0
40	Feed	11.0	41.5					100.0	1.17	41.5		100.0	0.0
	Rougher	11.0	41.5	10	300	23.0	4.56	67.3	1.64	14.4	0.20	94.4	78.8
	Clean	7.4	13.1	10	250	18.3	4.56	30.1	3.52	0.0	0.12	90.6	100.0
	Reclean	3.3	0.0	10	100	12.5	4.56	8.5	11.89	0.0	0.23	86.3	100.0

* The slime tailing contains quartz, microcline, topaz, wolframite, pyrite, molybdenite, molybdite, fluorite, mica, sphalerite, chalcopyrite, galena, and monazite.

** Acoustical pressure measured immediately below the bottom of the glass tube.

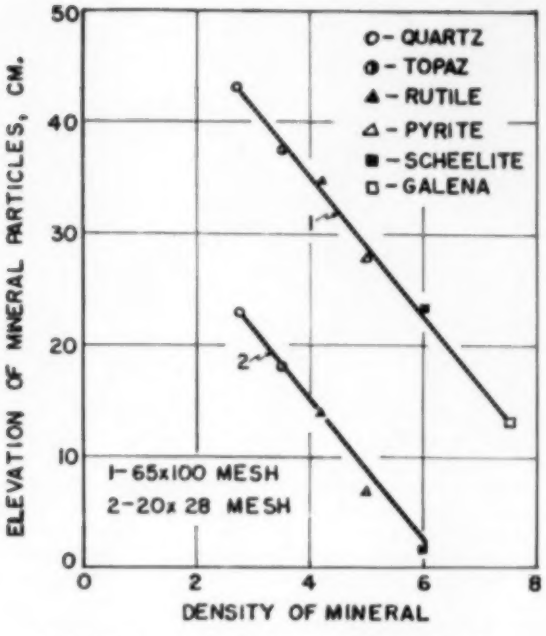

Fig. 2—Effect of density of mineral particles on their ultrasonic elevation in water, tested in a glass tube of 2.43 cm ID and with an acoustical pressure of 3.8 x 10^6 dynes per cm^2 below the bottom of the glass tube.

only an approximation, because of the oscillation of the particles. In another series of tests, the attenuation[9, 10] of ultrasonic waves in water was measured with a ceramic probe microphone[11] and a Hewlett Packard vacuum tube voltmeter.

Rationalization of the experimental data, as shown in Figs. 1 to 4, has been obtained by contending that ultrasonic stratification is controlled by the balance between upward and downward forces acting on the different mineral particles in the vertical pulp column. The upward forces, consisting chiefly of radiation pressure[1, 2] and partly of acoustical streaming,[12, 13] increase directly with the intensity of the incident sound waves. Owing to the attenuation of sound waves in the pulp, the upward forces are dampened from bottom to top. The downward forces, consisting chiefly of gravity and partly of fluid resistance, increase with an increase in the density and/or size of the particle. Elevation of any particle occurs only when the sum of the upward forces is larger than that of the downward forces and continues until these two sets of forces reach an equilibrium. For any given sound source, the equilibrium elevation of the fine-light particles is higher than that of the coarse-heavy particles, thereby producing stratification.

Mathematically, the motion of an ultrasonically irradiated mineral sphere in water can be roughly expressed by Newton's second law of motion as:

$$F_e - F_g - F_r = ma \qquad [1]$$

in which F_e, F_g, and F_r are, respectively, the force of elevation, gravity, and resistance; m is the mass of the mineral sphere; a is the upward acceleration; each is expressed in CGS units. Eq. 1 indicates that the sphere is ascending when $F_e - (F_g + F_r) > 0$, or $F_e > (F_g + F_r)$. The greater the difference between F_e and $(F_g + F_r)$ the greater the upward acceleration of the sphere. Eq. 1 can be written in detail as:

$$4\pi r^2 \left(\frac{k_1 I}{V_s} + \frac{k_2 \Delta' V_s^2}{2} \right) - \frac{4}{3} \pi r^3 (\Delta - \Delta') g$$

$$- 6\pi u r v = \frac{4}{3} \pi r^3 \Delta \frac{dv}{dt}. \qquad [2]$$

Terminal velocity can be obtained by putting $dv/dt = 0$, whence,

$$v_t = \frac{2}{9u} \left[3r \left(\frac{k_1 I}{V_s} + \frac{K_2 \Delta' V_s^2}{2} \right) - (\Delta - \Delta') r^2 g \right] \qquad [3]$$

in which r, Δ, and v are, respectively, the radius, density, and velocity of the sphere; Δ' and u are, respectively, density and viscosity of water; g is the gravitational acceleration; k_1 and k_2 are, respectively, the correction factor for the pressure of radiation and streaming; I and V_s are, respectively, the intensity and velocity of the incident sound waves; and V_s is the velocity of the streaming water. Eqs. 2 and 3 show that, for any given sound source, the upward acceleration and terminal velocity of a sphere increases with a decrease in its density and/or size.

When the sphere is not moving, or under equilibrium condition, then F_r and a of Eq. 1 are both equal to zero, and Eq. 2 reduces Eq. 4.

$$p = \frac{k_1 I}{V_s} + \frac{k_2 \Delta' V_s^2}{2} = \frac{1}{3} r (\Delta - \Delta') g \qquad [4]$$

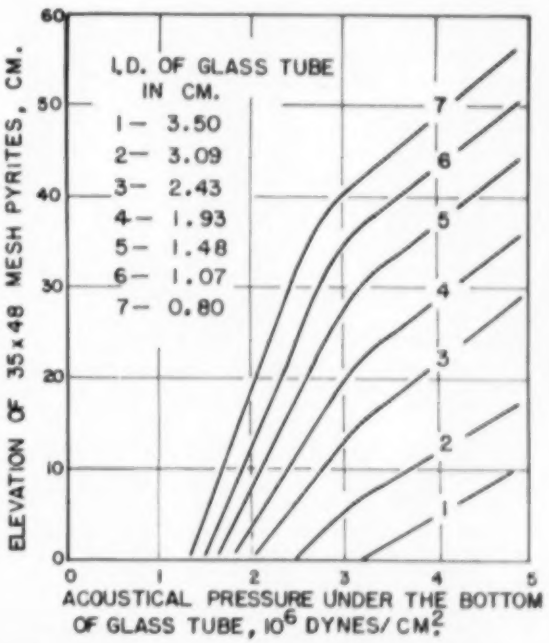

Fig. 3—Effects of acoustical pressure and glass-tube diameter on the elevation of 35x48 mesh pyrite particles, tested with a hypersonic transducer of 400 kc per sec sound frequency.

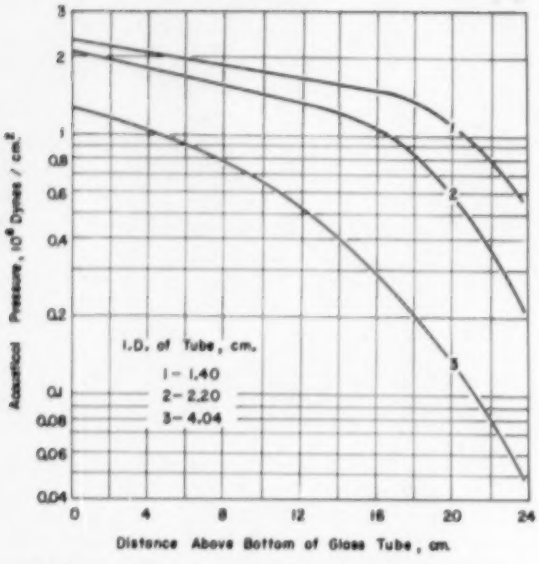

Fig. 4—Attenuation of acoustical pressures in vertical water columns contained in glass tubes of different diameters. Gap between bottom of glass tube and bowl surface of hypersonic transducer, 7.0 cm; length of tube, 25 cm; acoustical intensity at bowl surface, 3.5 x 10^6 dynes per cm^2; sound frequency, 400 kc per sec.

in which p is the acoustical pressure. On the basis of Fig. 4, the diminution of acoustical pressure with distance can be generally expressed as:

$$p = a + be^{-bx} - ce^{lx} \qquad [5]$$

in which x is the distance up from the bottom of tube; a is the pressure at the inflection point of the curve plotted on cartesian coordinates, occurring only when the sonic reflection at the upper surface of water becomes important; k and l are constants that determine the slope of the curve; b and c are constants; and e is the Napierian base of logarithms. The term be^{-bx} represents the decrease of pressure with distance in the straight line portion of the semilog plot, as shown in Fig. 4. The term ce^{lx} represents the curved portion of the plot, as caused by the sonic reflection at the upper surface of water; and factors a, b, c, k, and l all depend on the geometry of the tube. Eqs. 4 and 5 show that the rising sphere sooner or later must stop, because of the gradual diminution of the upward forces, and that the equilibrium elevation increases not only with a decrease in the density and/or size of the sphere, but also with an increase in the incident sound intensity.

The above equations do not pretend to absolute accuracy but are sufficient to show the underlying causes of the experimental phenomena. For example, Figs. 1 and 2 show that when the upward forces are held constant the fine-light particles are elevated higher than the coarse-heavy ones. According to the above equations, the higher equilibrium elevation of the fine-light particles is attributed to their larger difference between upward and downward forces. Under such conditions, stratification can take place on the basis of the density and/or the size of the particles. Fig. 3 shows that when the downward forces are held constant the elevation of 35x48 mesh pyrite particles occurs only when the upward forces are appreciable; it becomes more pronounced as the upward forces are increased. In accordance with the above equations, the difference between opposite forces and consequently the equilibrium elevation of any given particle increase directly with its upward forces. Fig. 3 also shows that, within a certain limit, the pyrite particles rise higher in a tube of smaller diameter than in the same length tube of larger diameter. This is because roughly the same power is channeled into both tubes, and hence the sound intensity, which is equal to power divided by area, is greater in the narrower tube.

Fig. 4 shows that the incident sound waves are gradually attenuated in their passage from bottom to top through a tube of water. Some of the reasons for attenuation are viscosity and heat conduction. This implies that, under suitable conditions, the upward forces at the bottom of the tube are just sufficient to elevate the fine-light but not the coarse-heavy particles all the way up the pulp column. At the top, the forces are weak and capable of preventing only the fine-light but not the coarse-heavy particles from descending. Such a condition is desirable for desliming and can be easily created by adjusting the sound intensity and/or the height of pulp column.

Apparatus and Procedure: Fig. 5 shows that the ultrasonic classifier used for intermittent desliming consists of a 400-kc hypersonic transducer, *A* and *J*; a feed preparing and regulating system, *B-D*; and a classifying system, *E-H*. The intermittent classifier can be converted into a continuous one by the addition of a vacuum system for evacuation of underflow.

Table II. Ultrasonic Desliming and Upgrading of Two Scheelite Ores

Test No.	Stage of Ultrasonic Desliming and Upgrading	Solid Feed: Particle Size, Mesh	Solid Feed: Weight, G	Solid Feed: −400 Mesh Slime, Pct	Pulp Dilution	Amount of Wash Water, CC	Length of Glass Tube, CM	Acoustical Pressure 10^6 x Dynes Per CM^2	Product (Underflow): Weight, Pct	Product (Underflow): Grade WO_3, Pct	Product (Underflow): −400 Mesh Slime, Pct	WO_3 in Overflow, Pct	WO_3 Recovery, Pct	Removal of −400 Mesh Slime, Pct
20	Ore No. 1*	−270	19.5	64.9					100.0	3.61			100.0	0.0
	Rougher	−270	19.5	64.9	6	400	8.4	3.06	38.0	8.98	7.6	0.32	94.5	95.8
20A	Ore No. 1a*	−270	19.8	64.9					100.0	3.52			100.0	0.0
	Rougher	−270	19.8	64.9	6	400	8.4	0.8	63.9	5.27	45.6	0.69	92.9	56.0
44	Ore No. 2**	−150	9.3	27.4					100.0	7.27			100.0	0.0
	Rougher	−150	9.3	27.4	15	230	23.0	1.62	80.6	8.97	9.9	0.18	99.5	71.0
	Clean	−150	7.5	9.9	15	200	18.3	2.96	68.9	10.36	0.0	0.86	98.2	100.0

* Ore No. 1 contains scheelite, calcite, fluorite, quartz, and clayey materials.
** Ore No. 2 contains scheelite, quartz, epidote, actinolite, limonite, and clayey materials.

Ultrasonic desliming was tested in the intermittent classifier by the following steps: 1) preparing the ore pulp to be tested in the graduated flask, *C*, of Fig. 5; 2) filling the glass tube, *F*, with water; 3) connecting the water inlet, *E*, to a water faucet by rubber tubing; 4) turning on the hypersonic generator, *A* and *J*; 5) opening the stopcock of the graduated flask and allowing the prepared ore pulp to flow into the glass tube, *F*, through the funnel tube, *D*; and 6) collecting both the overflow and underflow for subsequent drying, weighing, analyzing, and sizing. Except where otherwise stated, the ore pulp of each test was prepared by agitating a mixture of 10 to 12 g dry ore, 0.4 lb per T sodium silicate, and 450 cc water in the graduated flask for 20 min. The feeding rate of pulp and water was set at approximately 0.5 and 0.1 cc per sec respectively. Throughout the test the feed was kept in constant agitation.

Desliming and Upgrading: The validity of the proposed ultrasonic method for desliming and upgrading of ores and tailings was checked by reclamation of wolframite from the −200 mesh slime tailing of a molybdenum ore. This slime tailing, containing 1 to 1.5 pct WO_3 and 38 to 42 pct of −400 mesh material, is the overflow of the hydraulic classifiers of a milling plant and has plagued investigators interested in reclaiming the tungsten. The test results, as given in Table I, indicate that the ultrasonic method can be used effectively to solve this problem. For example, test 39 shows that, under suitable conditions, a one-step desliming is sufficient to remove all fine slime particles from the tailing, resulting in a product of 25 pct WO_3 and 83 pct tungsten recovery. Test 40 shows that when the glass tube used is unduly long the desliming and upgrading have to be performed with more steps and stronger sound intensity. The tungsten content of the deslimed product could be further increased by flotation.

The ultrasonic method was also tried on the desliming and upgrading of two scheelite ores and proved to be satisfactory. Comparison of tests 20 and 20A, Table II, shows that an optimum acoustical pressure is absolutely necessary for efficient desliming and upgrading. Test 44 shows that the slime particles of a high grade tungsten ore can be totally removed with very little loss of scheelite.

The ultrasonic method was still further checked by testing the slime tailing of a Chinese tin ore. This slime tailing, containing 0.978 pct tin and 95 pct of −400 mesh material, is the combined overflow of the hydraulic classifiers and cones of the Kochiu mill[4] at Yunnan, China, and has been a plant waste for more than 200 years. Most of the fine slime particles come from the naturally accosiated clayey materials of the ore while the remainder are the result of overgrinding. Test results, as plotted in Fig. 6, show that the ultrasonic method is fairly effective in desliming and upgrading this tailing. This is exemplified by the fact that using a tube 23 cm long and applying an acoustical pressure of 2.4 x 10^6 dynes per cm^2 beneath the tube will remove 82 pct of the −400 mesh slime, giving a deslimed product of 3.2 pct tin with a 76 pct tin recovery. As a result of ultrasonic desliming, this previously nonfloatable tailing becomes a workable flotation feed. In addition, Fig. 6 shows that the tube 8.4 cm long gives the highest grade of product but at the sacrifice of tin recovery. The reverse is true for the tube 51.5 cm long. The optimum acous-

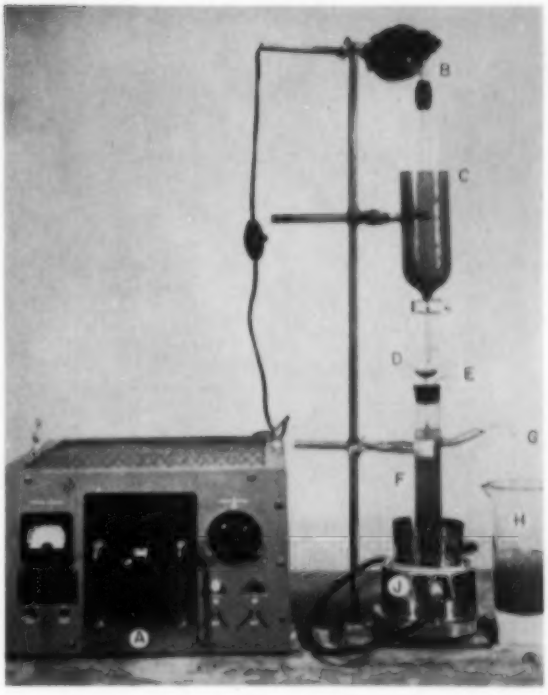

Fig. 5a—Ultrasonic classifier used for intermittent desliming

A. Hypersonic generator
B. Stirrer
C. Graduated flask
D. Funnel tube
E. Water inlet
F. Glass tube, 3.1 cm ID
G. Overflow arm
H. Beaker
J. Transducer bowl, 400 kc per sec frequency

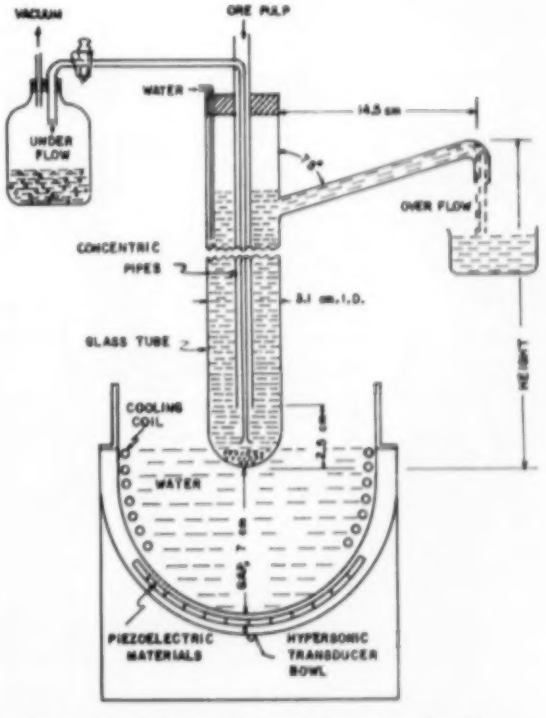

Fig. 5b—Ultrasonic classifier used for continuous desliming.

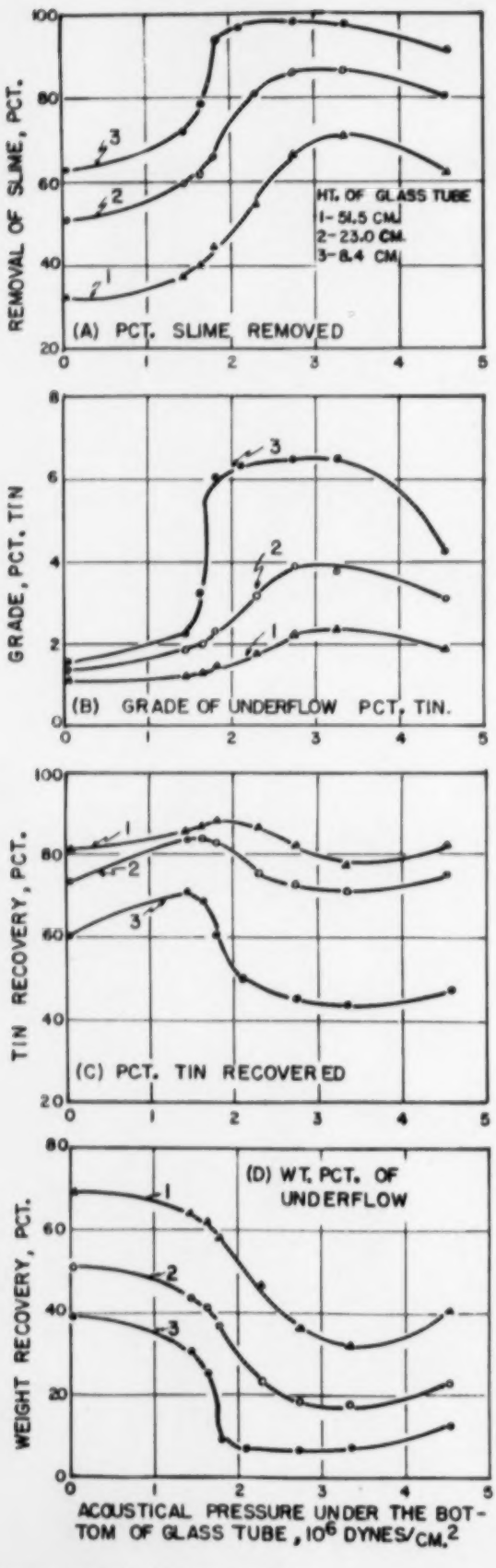
REMOVAL OF SLIME, PCT.
HT. OF GLASS TUBE
1- 54.5 CM.
2- 23.0 CM.
3- 8.4 CM.
(A) PCT. SLIME REMOVED
GRADE, PCT. TIN
(B) GRADE OF UNDERFLOW PCT. TIN.
TIN RECOVERY, PCT.
(C) PCT. TIN RECOVERED
WEIGHT RECOVERY, PCT.
(D) WT. PCT. OF UNDERFLOW
ACOUSTICAL PRESSURE UNDER THE BOTTOM OF GLASS TUBE, 10^6 DYNES/CM.^{2}

Fig. 6 (left)—Ultrasonic desliming and upgrading of Kochiu tin ore tailings, which contain 0.978 pct tin and 95 pct —400 mesh slime. Solid sample, 10 to 12 g; pulp dilution, 50:1; wash water, 100 cc; gap between bowl and tube, 7.0 cm; and sound frequency, 400 kc per sec.

tical pressures for desliming were moderate in magnitude for all the tubes tested.

For comparison, the two slime tailings were also tested with a home-made sullivan deck,[16] a laboratory cyclone, and a four-column hindered settling classifier.[16] The experimental data, not presented, showed that the above conventional methods were less effective than the ultrasonic method for desliming and upgrading these particular slime tailings. The slime particles, because of their extremely fine sizes, were difficult to remove by the conventional equipment without excessive loss of the valuable particles. This difficulty was considerably reduced chiefly by the ability of the ultrasonic waves to disperse the aggregates of valuable and clayey materials and to clean the surface of the values, resulting in a larger quantity of better flotation feed. An additional advantage of the ultrasonic method is that the acoustical forces are subject to easy and accurate control over a continuous range of magnitude.

Summary

1) An ultrasonic method is proposed to deslime and upgrade ores and slime tailings of fine particle sizes. Although the test results on tungsten and tin samples are promising, it is realized that tests should be made with larger equipment before the applicability of this method can be ascertained.

2) The ultrasonic stratification of mineral particles in water is experimentally verified.

Acknowledgment

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aime news

Pacific Northwest Regional Conference Highlights

More than 300 engineers attended the AIME Pacific Northwest Regional Conference at the Olympic Hotel in Seattle. Thirty-five mining engineering students from six western colleges and universities registered.

This *Granddaddy* of AIME regional meetings ran from May 3 to 5th, and included 39 technical papers by experts in the fields of mining, metallurgy, and petroleum engineering. Technical sessions filled the first two days of the meeting, while Saturday was devoted to tours through industrial plants in Seattle, Renton, and Tacoma.

The students came from the University of Nevada in Reno, the Montana School of Mines at Butte, the University of British Columbia at Vancouver, the State College of Washington at Pullman, and the University of Washington in Seattle.

The AIME North Pacific Section, which sponsored the conference, encouraged student attendance by waiving the registration fee, giving reduced hotel room rates, and offering conference luncheon and banquet tickets to students at half-price. A special student dinner Thursday evening was provided by the Colorado Fuel & Iron Corp. and the Harvey Aluminum Co. of U. S. A technical session on minerals industries' education followed the dinner.

Seattle's Mayor Pomeroy extended a cordial welcome at the Metals Branch luncheon, and stressed the need for more college engineering graduates.

J. Gordon Parr, associate professor of metallurgy, University of Alberta, spoke at the luncheon on Thursday. His entertaining and informative talk lived up fully to the promise of its title, *How Does the Metallurgist Get the Urge?*

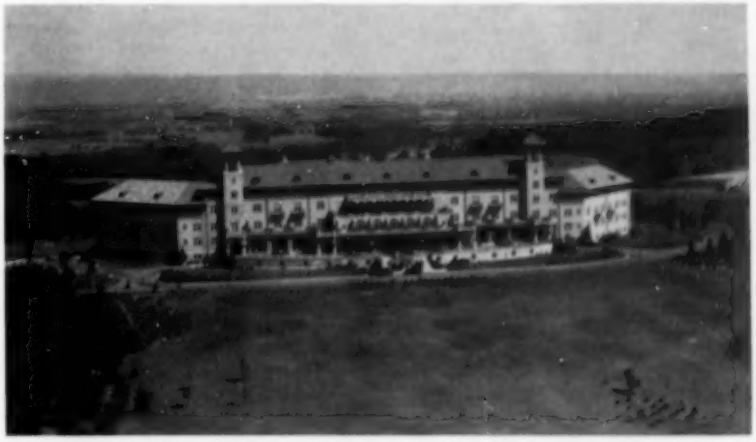
Desmond F. Kidd, Past-President of CIM, and president and general manager of Attwood Copper Mines, Ltd., spoke at the Mining Branch luncheon Friday on *This Progress of Ours.*

Grover J. Holt, general manager of ore mining for The Cleveland-Cliffs Iron Co., Ishpeming, Michigan, and President-elect of the National AIME addressed the conference banquet at 7 pm Friday. His topic, *Indian Warpaint in our Lives Today*, showed the progress in iron mining from the days when iron ore was used only for Indian warpaint, to the present when 87 million tons of ore were mined in the Lake Superior district alone in 1955. This is enough ore to fill a single train 6,600 miles long, originating in Minnesota and extending through Seattle to Tokyo, Japan. In the 100 years since iron ore was first mined in the U. S., three billion tons of ore have been produced, which would fill a train long enough to circle the world nine times at the equator.

This rapid depletion of our known reserves of high-grade ore has forced industry to develop, through research, methods of recovering iron from low-grade taconite ores, of which tremendous reserves are available. Mr. Holt pointed out that as a result of this research, industry has more than replaced the iron ore mined out in the past.

Mining and metallurgical students (standing), were treated to a special dinner at the AIME Pacific Northwest Regional Conference. Seated from left to right: H. Lovenstein, E. R. Marble (General Chairman of the Conference), Charles E. Golson, Roy O'Brien (AIME Field Secretary), K. N. McLeod, David S. Gleason and Dean John P. Spielman.

Mining Branch Schedules November Meeting



The luxurious Hotel Hershey in Hershey, Pa., overlooking the famous gardens containing 42,000 varieties of rose bushes, will be the site of the AIME Northeastern Mining Branch Conference scheduled for November 8-10, with Lehigh Valley Section as host.

An AIME Report:

Long Range Planning For Institute Development

The Background

SINCE its founding 85 years ago the AIME has continued to grow from the original small group of compatible mining engineers to the present complex association of engineers bonded together by their mutual professional interest in exploration, development, extraction, or conditioning processes of the world's great mineral resources. At times this growth process has been slow, but more recently it has increased at an accelerated pace. At the end of 1934 there were 7,163 nonstudent members of the Institute; at the end of 1945 there were 12,910; at the end of 1955 there were 23,723 nonstudent members. The student membership, in stride with the trend, has increased from 579 at the end of 1934 to 2825 at the end of 1955.

Correlative with this growth in numbers has been a blossoming of mineral technology until today the primary interests of the membership are represented conjointly in the three Branches: Metallurgy, Petroleum, and Mining. The Metallurgy and Mining Branches include Divisions, representing technical specialization, that are in turn composed of committees or groups of increased specialization, until today there are undoubtedly more committeemen in any one of the Divisions than there were in the total membership of the original group that founded the Institute.

As the membership has increased, and as the scientific interests of the members have broadened and deepened, so has the complexity of the administration of the AIME increased. Reorganization has followed organization throughout the history of the administration. Several of the reorganizations have demanded changes in philosophy as to methods of serving the membership more effectively. A typical example of this was a reorganization in 1911 when the first three Local Sections were established. The need for maintaining communications in the Institute as it gained in size as well as the need to overcome the handicap of the distances of groups of members from headquarters undoubtedly compelled what at that time must have been a revolutionary concept to the men who were guiding the destiny of AIME. By 1948 the number of Local Sections had increased to 41, and today we have 70.

More recently, in 1947, the Board of Directors of AIME appointed a committee of M. M. Leighton, Clayton Ball, and H. W. Johnson to study the *Divisionalization and Publication Program* of the Institute. The report of this committee has become known as *The Johnson Report* and was published in the March 1948 issue of MINING AND METALLURGY. Many of the concepts introduced in the report have been incorporated into the fabric of the Institute as we know it today. Although the report was written ten years ago when the total membership was only perhaps 60 pct of that of today, many of the conclusions remain pertinent. Members who are interested in the history and development of the Institute would do well to reread *The Johnson Report*.

Early in 1955, E. H. Robie forecast that the nonstudent membership of the Institute would increase to 27,000 in 1960; 31,000 in 1965; 35,000 in 1970; and to 43,000 in 1980. Again, with increases such as these, the complexity of the problems of administration, especially of the staff functions, will multiply. With this in mind, H. DeWitt Smith, as President of AIME, appointed a committee which he designated as a Long Range Planning Committee to study AIME organization and to recommend means of simplifying the mechanics of operation of the Institute now and in future days of growth. The committee consisted of Andrew Fletcher, 1953 AIME President (Mining) as Chairman; Leo F. Reinartz, 1954 AIME President (Metals); and Carl E. Reistle, Jr., 1956 AIME President (Petroleum).

During the course of the comprehensive study, the committee solicited advice from the members of the AIME Board, the Branch Councils, the Division Chairmen, and other members who had official responsibilities in the activities of the Institute. Thoughtful communications numbered in the hundreds, and uninformed criticism was rare. The advice of Norman Mitchell, member of A. T. Kearney & Co., Chicago, who was a consultant for the Johnson Committee, was also invited.

Previous to the Annual Meeting in New York in February of this year, the committee on Long Range Planning submitted the first draft of its report to the Board of Directors, the three Branch Councils, the Chairmen of the Local Sections, and to the Council of Section Delegates. By broadcasting this draft in advance of the annual meeting, the committee provided, to a large segment of the membership, an opportunity to study and discuss the tentative plan. The report was widely discussed by the various groups at the annual meeting and most of the proposals in the plan were well received. However, the discussion proved that two or three of the proposals needed clarification or modification.

At the final meeting of the 1955 Board, a revised Long Range Planning Report was received by the Board with a vote of thanks to the committee. The Long Range Planning Committee was discharged and the report was passed on to the 1956 Board. At the first meeting of the new Board, President Reistle appointed a committee of the chairmen of the three Branches and the chairman of the Council of Section Delegates to study or work out some of the organizational details and modifications that would be required to implement the plan. This committee was charged to work within the framework of the Long Range Plan; it was cautioned not to come forth with a new Long Range Planning Report. The new committee will report to the Board at the June 1956 meeting.

Although the Long Range Planning Report has had wide circulation among the technical and administrative groups and the Local Sections of the Institute, there is perhaps a segment of the membership that is not affiliated with Local Sections and that has not been able to attend local, regional, or annual meetings. For the benefit of these members, the report is being reproduced here. The membership is invited to study this report and to comment on the proposals.

The Report

The Committee composed of one representative from each of the three Branches was given, in February 1955, the responsibility of developing long range planning for the AIME.

Two memoranda outlining possible solution of certain operating problems, finance, publication, meetings, membership, development, and other related matters, were prepared and submitted to representative members of the Institute to obtain their reaction. A third memorandum was presented to the Board meeting of Nov. 16, 1955.

Based on the very competent letters and meetings with members of the Institute, and supplementing the report, dated Dec. 20, 1955, of Norman Mitchell, member of A. T. Kearney & Co., Chicago, who was appointed by President Smith in November to make an objective study of the Institute and its problems, your Committee makes the recommendation to maintain the general structure of the AIME as it now exists, but with the following changes in structure and organization:

1. Name

a. The name should be *American Institute of Mining, Metallurgical, and Petroleum Engineers.*

b. The abbreviation of *AIME* should be retained.

c. The symbol should be redesigned by including in the background a drilling derrick or some other item that is representative of the petroleum members.

2. Branches

a. The subdivision of the membership groups should no longer be known as Branches but as Societies, and under the following titles:
Mining Engineering Society of the AIME
Metallurgical Engineering Society of the AIME
Petroleum Engineering Society of the AIME

b. Each society should form its own committee on education and on economics, in accordance with its own need. These committees would then be coordinated by an AIME council, or professional division, that would have a representative on the AIME Board of Directors. This Council would cover all three Societies in the Institute, and all AIME members could participate in it, as well as belong to their own Society.

c. Subject to the approval of the AIME Board, each Society should organize its own Executive Committee, with officers and bylaws.

3. Directors

a. The number of AIME Directors should be reduced to 21, and the honor and responsibility of office be increased.

b. The President, President-Elect, and Past-President should serve as Directors. Each society should have its own Nominating Committee for the election of its Directors, and six additional Directors from each Society should serve as Board members. In the first year of reorganization, two Directors would be elected for three years, two for two years, and two for one year; thereafter, two would be elected each year by each Society for three-year terms.

c. Transportation, but not food or housing expense, of any Director to the four quarterly Board meetings, should be paid by the AIME.

d. The duties of the Board should be to establish the broad policies of the AIME, to maintain and protect the integrity and professional standing of the members, to plan and be responsible for the Annual Meeting, to handle the joint finances of the various groups, and to review and approve the recommendations of the President for membership on the standing committees. The Board should also have the power to approve or disapprove any changes in the organizational setup or financial policies of the individual Societies.

4. President

a. Each society should name the President every third year. The Nominating Committee of the individual society from whom the President is to be elected should make the nomination for that particular year.

b. The President's transportation, but not food or housing expense, should be paid by the AIME with an upset limit to be determined annually by the Board.

5. Sections

a. As sections over the coming years will be influenced more by professional than by geographical lines, each Society should be given authorization to set up its own geographical areas and organize sections to meet its requirements. Until changed by the Board, the minimum requirement for the setting up of any section should continue to be 25 members.

b. Local sections can and should be flexible in their organization and operation. Some may be organized on a geographical basis, and some on a professional basis. It was not the intent of the Long Range Planning Committee to force a reorganization of local sections, but to let each section have the freedom to organize according to the needs and wishes of its membership. The Council of Section Delegates may be continued as an all-Institute organization, with its functions changed somewhat and some organization of section delegates on a society basis.

6. The Council of Section Delegates

a. As the Council has many desirable features, the Committee recommends that each society should set up its own Council of Section Delegates, whose primary responsibility should be to keep the Directors of that particular society informed. If, however, a society does not desire to have its own Council of Section Delegates, it will be under no obligation to do so. The society should pay the expenses of its own Council.

7. Initiation Fees and Dues

a. The Committee recommends that for the next three-year period initiation fees should be reduced from $20 to $10, and the respective Society be refunded the $10.

b. The Committee believes that the dues for all three societies should be the same, and that for the time being at least, the $20 fee should be retained.

c. The Committee recommends that the refund of 50 cents a member should be continued, but that for the next three years, while the suggested reorganization is taking place, the refund should not be any greater.

d. The AIME Board should have the right to reduce or increase the initiation fees, dues, or rebates any time upon a majority vote of the Board members.

8. Finances

a. Each society should have full responsibility for operating at a profit, as shown by the AIME books. After expenses have been met, each society should have authority to spend all surplus funds after 25 percent of such surplus funds have been set aside for the interests of the AIME as a whole.

9. By-laws

a. The AIME By-laws should be rewritten and simplified.

10. Meetings

a. The Committee recommends to the Board that a decided change should be made in the Annual Meeting program. For example, the number of technical sessions should be reduced, one or more joint sessions of the three societies be organized, and luncheon meetings be addressed by outstanding speakers on timely subjects of a general nature.

b. All business should be divorced from the Annual Banquet and only top awards should be given at that time. The other awards should be given at society or regional dinners or meetings, which it is believed will be strengthened by the transfer to them of some of the technical sessions.

c. The President should make his report on *State of The Institute* at an afternoon session during the Annual Meeting.

11. Conclusion

It is hoped that the above suggestions and comments will result in each Society having as much autonomy as possible, and that the AIME will grow into a single and stronger Institute in which the best interests of all members are furthered.

COMMITTEE FOR AIME LONG RANGE PLANNING
Leo F. Reinartz—Metals
Carl E. Reistle, Jr.—Petroleum
Andrew Fletcher, Chairman—Mining

Around the Sections

A new Subsection of the Arizona Section has been organized, to include members residing in Yavapai County, of which Prescott is the county seat. John W. Still is Chairman; J. D. Lowell, Vice Chairman; Mark Gemmill, Secretary-Treasurer; and Fred Gibbs and K. L. Erickson, additional Directors.

All mining branch members who live in Southwestern Wisconsin, Northeastern Iowa, and Northwestern Illinois and would be interested in joining or aiding in the planning of AIME activities in their area, are urged to write to Wayne R. Zwickey, Secretary, Steering Committee, Upper Mississippi Valley Section, AIME, Box 217, Platteville, Wisc.

• A meeting sponsored by Michigan College of Mining and Technology, the Geological Society of Michigan, and the **Exploration Subsection** of the **Upper Peninsular Section AIME**, was held by the Institute of Geology on May 11 and 12 at Michigan Tech., Houghton, Mich. Grover C. Dillman, president of Michigan Tech., made the welcoming address. At the opening session, A. K. Snelgrove of Michigan Tech., introduced C. E. Dutton of the U. S. Geological Survey, Madison, Wis., who acted as chairman for the program. During the three technical sessions several interesting papers were presented including: "The Regional Geological Setting of the Michigan Copper District," by Walter S. White, USGS, Washington, D. C.; "Geological Factors Affecting Beneficiation of Lake Superior Iron Ores," by M. E. Volin, Michigan Tech.; and "Trends in Geochemical Exploration," by H. E. Hawkes, Jr., Massachusetts Institute of Technology. A dinner was held on Friday with Frank Kerekes, Dean of Faculty, Michigan Tech., acting as chairman. Mr. Kerekes introduced George C. Marvin, assistant director for process development of raw materials, U. S. Atomic Energy Commission, Washington, D. C., who spoke on atomic energy development and its relationship to the mineral industry. On Sunday, May 13, field trips were made to the Marquette iron range, Ishpeming, Mich., and to the White Pine Copper Co., White Pine, Mich. The meeting was attended by 174 persons.

• The **Southwestern New Mexico Section** met on March 22 in the Bayard Lions Club building. The Chairman, Ben Shantz, announced that AIME President, C. E. Reistle, Jr., planned to visit the Section on May 25. W. H. Goodrich gave a talk in which he paid tribute to the late Daniel C. Jackling. The Section Delegate, G. J. Ballmer, reported on the AIME Annual Meeting. Charles Kuzell, vice president and a director, Phelps Dodge Corp., spoke on the AIME long range planning program. H. A. Wilmeth, Chairman of the Program Committee, announced the appointment of Clarence Snell, Elton Clark, Harrison Schmitt, and Charles Lockart, as members of his committee. The annual picnic for 1956 was discussed and the date set tentatively for June 16.

• The **New York Section** met on April 26 at the Mining Club. The principal speaker was Nathaniel Arbiter, professor of mineral dressing, Columbia University. His talk covered the various methods available for extracting copper from oxidized ores. Mr. Arbiter has a patent for the flotation of chrysocolla. Because of current interest in copper prices, George H. Cleaver, market editor, *Metal and Mineral Markets*, discussed the prices published by *E&MJ*. The Chairman, H. Z. Stuart, gave the annual section report and introduced the new section officers for 1956.

• The **Minerals Beneficiation Subsection** of the **Minnesota Section** met on May 9 in the Servicemen's Center, Chisholm, Minn. The principal speaker for the evening was Luther Hendrickson of the Oliver Iron Mining Div., U. S. Steel Corp. His subject was "Zinc Metallurgy at Flin Flon." Mr. Hendrickson spent several years at Flin Flon before going to the Lake Superior area.

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Columbia Section Meets

The fourth official annual student meeting of the AIME Columbia Section was held at the University of Idaho on Sat., May 12. These joint meetings of the student societies of Washington State College and the University of Idaho, alternate between the two campuses; this year the hosts were the Associated Miners—students in the College of Mines of the University of Idaho.

At these official Columbia Section meetings the student officers preside, and all the technical talks are given by students. This year, as in previous years, a technical session was held in the afternoon followed by an evening banquet. Presiding officers for the technical session and the banquet were the presidents of the two student societies—John A. Blessinger of the University of Idaho and Alf Eikum of Washington State College. Speakers and topics included: George Anthony Hayes who discussed *Use of Rare-Earth Elements in Stainless Steels;* Ben Wilcox who detailed *Nitriding of Titanium,* Con Pilz spoke on *Refining of Sunshine Electrolytic Antimony.*

Jerry M. Whiting followed with a talk on *Pre-Cast Concrete Supports for Mine Workings,* and Neal Jacques described the *Theory of Use of Rock Bolts in Unstratified Deposits.*

The concluding speaker was Lewis V. Girard who outlined *Current Economic Aspects of Nez Perce and Asotin County Limestones.*

The afternoon session was in the campus Student Union Building, and the banquet, attended by 75, was held in the main dining room of the Moscow Hotel.

J. B. Haffner, counselor for the two student chapters, who spoke at the banquet, announced that the Columbia Section is awarding a prize to each of the six student speakers. This prize consists of a technical book (or books) chosen by each speaker, up to a value of $12.50.

Mrs. J. D. Forrester entertained the visiting ladies at a tea and social in the afternoon, and some of the visiting engineers were taken on an inspection trip of the nearby clay deposits. The meeting was well attended and the performance of the students made a very favorable impression on all the visitors.

NOHC Meeting Planned

The Eleventh Annual Off-the-Record Meeting of the Pittsburgh Sections of AIME and NOHC will be held at the William Penn Hotel in Pittsburgh, on November 2, 1956.

Sessions will be held on coal, petroleum and gas, physical metallurgy, open hearth operations, extractive non-ferrous metallurgy and nonmetallic minerals. There will be an informal luncheon, and a cocktail party and banquet in the evening.

Those wishing copies of the program and registration forms may send their request to Shadburn Marshall, Secretary, Pittsburgh Section, AIME, Atomic Power Div., Westinghouse Electric Corp., Bettis Field, Pittsburgh.

NOTICE:::

Mining Branch Office has a LIMITED number of the 1956 Annual Meeting Mining Branch Abstract Booklets available for distribution to those who request copies from Arnold Buzzalini, Mining Branch, AIME, 29 West 39th St., N. Y. C. 18. Abstracts of the following divisions are included in this booklet: Mining, Geology and Geophysics Div., Industrial Minerals Div., Mineral Economics Div., and Mineral Industry Education Div. There is no charge for this service. Booklets will be sent out on a first come first served basis.

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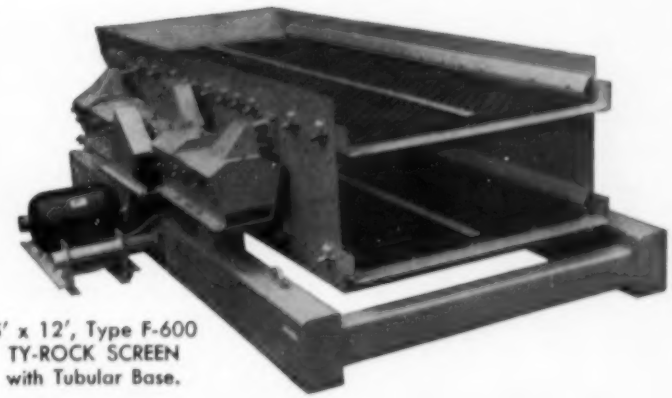

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Next Annual Meeting Scheduled for February 1957 in New Orleans

At the Annual Meeting in New Orleans, Feb. 24-28, 1957, the Mining and Petroleum Branches will make the Roosevelt Hotel their headquarters, the Metals Branch, the Jung Hotel. Tuesday afternoon from 2:15-4:15 will be devoted to an all-Institute program without conflicts. The session will include the Institute's Annual Business Meeting, a review of the year by the President, and a talk by a prominent speaker on a subject of importance and general interest.

The Executive Committee has also voted that no division can hold concurrent sessions. However, the three subdivisions of the mining, geology and geophysics division may hold simultaneous sessions. Thus, the maximum number of sessions that any division, except MGG, can hold will be seven. No Friday sessions may be scheduled. Should more papers be accepted than can be scheduled, the overflow will be directed to divisional, branch, or regional meetings at other times and places. As yet no post-convention trips have been planned. It is felt that Lima, Peru is too distant to be considered.

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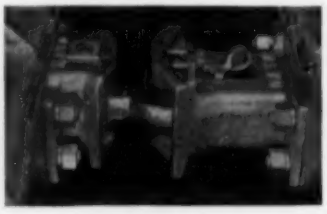

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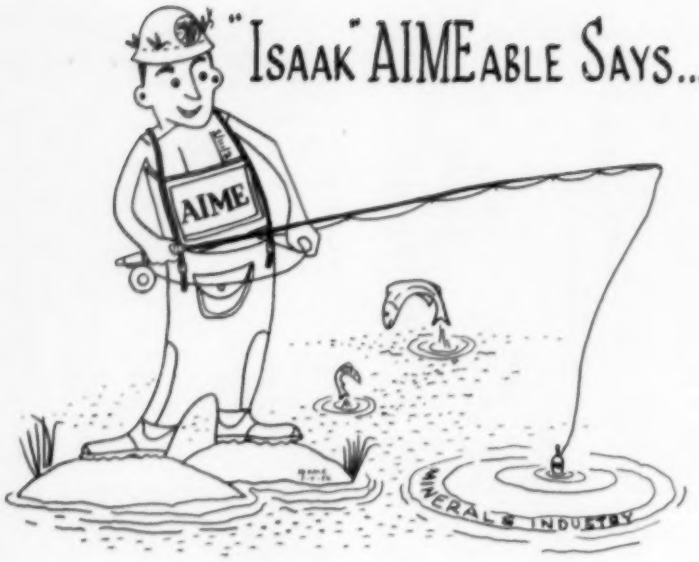

KEEP FISHING FOR GOOD MEMBERS THERE IN THE POOL

The days of the fishing stories have come around once more. Usually these stories are not about those that were caught, but about the *whopper* that got away.

Ole Isaak AIMEable, in those lucid moments when the fishing fever is not upon him, although he brags about those he nailed, and how the *beastie* fought to get away, gives some thought to those *beauties* at the bottom of a pool, or under some rock in the stream, who do not even rise to his lure.

If you ask a successful fisherman the reason why he brings back a creel full, while his next door neighbor usually comes home empty-handed, he will tell you it is a question of patience. Patience to learn the lore of the sport, and patience in fighting the fish, till you bag him.

It is a funny thing but this same quality of patience and pertinacity, is one that we need in signing up new members for the Institute. We need patience in locating the big ones; patience in a cautious approach, so as not to scare him away; patience in answering his objections and overcoming his resistance; patience once we have him on the hook, to get his application blank filled out and signed; then we finally have him.

We have not surveyed the membership of AIME to find out just what proportion are devotees of the sport of fishing, but my guess is that it will be quite high, so here's an appeal to you *Waltons* of this day! Why not imitate ISAAK AIMEable and fish for new members?—*C. E. Golson.**

* *Chairman, AIME National Membership Committee.*

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PERSONALS

T. D. JONES

T. D. Jones, chief lead refinery metallurgist, American Smelting & Refining Co., was one of six prominent graduates of the College of Engineering, University of Wisconsin, awarded a Citation for distinguished engineering services on Engineers Day, May 4. Mr. Jones received a B.S. in metallurgy from the university in 1922, and the professional degree of metallurgical engineer in 1929. He was chairman of the Extractive Metallurgy Div. of the AIME in 1952, and is a member of the Institute Admissions Committee, National Steering Committee, and the EMD Executive Committee.

John J. Craig will be consultant on iron ore and steel for Cyrus Eaton, chairman of the board, Chesapeake & Ohio Railway, and Steep Rock Iron Mines Ltd. Mr. Craig's first assignment is participation with Canadian and European experts in metallurgical work on the iron ore deposits in the Ungava Bay area of northern Quebec. A pioneer in the beneficiation of low grade iron ores, he was associated with E. W. Davis, professor at the University of Minnesota. Mr. Craig comes to his new post from ten years with the engineering firm of Arthur G. McKee & Co., Cleveland.

Francis B. Speaker has been appointed consultant on mining in the office of minerals mobilization. During World War II he was chief of the nonferrous metals division, War Production Board, and director of the Mining Div., Defense Materials Agency during the Korean War. Mr. Speaker operated copper mines in Arizona and Mexico before World War II. At present, he is employed in an engineering capacity by Hewitt-Robins Inc., Stamford, Conn.

Blair L. Sackett has retired as metallurgical manager of Tooele smelter operations, Anaconda Co., a subsidiary of International Smelting & Refining Co., in Salt Lake City. A member of the firm since 1912, Mr. Sackett also served as consultant for their exploration dept. He is succeeded by **Carlos Bardwell** who was superintendent of the Tooele plant. Mr. Bardwell joined Anaconda-International 43 years ago, after receiving his B.S. degree in chemical engineering from the University of Utah. Both men are former AIME Utah section chairmen.

Other company promotions are: **G. A. Burt,** assistant metallurgical manager, Salt Lake City; **W. J. McKenna,** general superintendent at Tooele; **E. W. Steinbach,** assistant general superintendent; and **T. W. Saylor,** lead plant superintendent.

Ingebrigt Jonsson has been appointed general superintendent of Mofjellet and Bleikvassli mines, A/S Nord Norge, Mo i Rana, Norway.

Michael C. Tournavitis, supervisor of inspection of mines, Salonica, Greece, is in the U. S. attending a one-year training program with the USBM, Denver.

George F. Leaming, assistant chief mine engineer, Braden Copper Co., Rancagua, Chile, has been called to active duty from the Reserves. He is now a lieutenant in the U. S. Army Ordnance Corps in Maryland.

Raymond E. Griffith, vice president in charge of refractory sales and engineering, E. J. Lavino & Co., Philadelphia, has retired. He will continue on the board of directors. **Gaylord T. Stowe,** formerly assistant vice president, has been elected vice president to succeed Mr. Griffith.

David K. Curtice has been promoted from assistant to geologist, Lone Star Steel Co., Lone Star, Texas.

Robert L. Mentch, who was commodity-industry analyst, USBM branch of base metals, has joined the research division of Merrill Lynch, Pierce, Fenner & Beane as a security analyst.

Phil Blazovic, Jr., has resigned as production manager, Carbola Chemical Co., Natural Bridge, N. Y., to accept the post of assistant manager, Consolidated Feldspar Dept., International Minerals & Chemical Corp., Erwin, Tenn.

Harold B. Coulter, formerly chief mechanical engineer for Dorr-Oliver Inc., in Stamford, Conn., has retired and is making his home in Los Altos, Calif.

Ronald F. Crawford, formerly sales engineer for Equipment Service Co. Inc., Birmingham, has retired and is residing in the same city.

E. Minor Pace, superintendent of Inland Steel Co.'s mines at Wheelwright and Price, Ky. since 1953,

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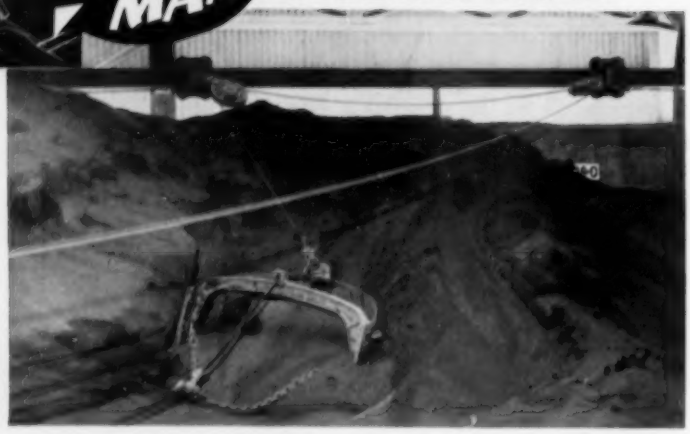

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(3) the operating cables and guide blocks.

(4) a method of shifting.

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has been promoted to general superintendent in charge of all Inland coal mining operations. A member of the firm since 1946, he left a year later to obtain his master's degree, specializing in mine ventilation, at West Virginia University.

Peter E. Fairbairn, consulting geologist, has joined the technical staff of Selection Trust Ltd., London. Mr. Fairbairn recently completed a five-month examination of mineral properties in Iran.

C. L. Sarff, formerly maintenance supervisor of White Pine Copper Co., White Pine, Mich., has joined the Hanna Coal Co. in St. Clairsville, Ohio.

E. E. Groff, formerly with American Smelting & Refining Co., Hayden, Ariz., has accepted the position of general superintendent of smelters, Mt. Isa Mines Ltd., Queensland, Australia.

E. Thomas Hight is mining construction engineer, project engineer, Reynolds Metal Co., Engineering Div., Richmond, Va.

Milton H. Fies, vice president in charge of coal operations, Alabama Power Co., Birmingham, has received the Conservation Service Award. This Award is given by the Department of the Interior in recognition of outstanding contributions to its conservation programs.

George E. Aiken is mining engineer, Nicaro Nickel Co., Santiago de Cuba, a subsidiary of Freeport Sulphur Co. Mr. Aiken graduated from the University of Minnesota with an M.S. degree in mining.

ADIN A. BROWN

Adin A. Brown is a director and vice president in charge of mining operations, American Smelting & Refining Co., New York. Mr. Brown was formerly general manager of the Mexican Mining Dept., El Paso, Texas, and has been with ASARCO since 1922. He succeeded **R. F. Goodwin** who retired. **C. F. Jordan** succeeded Mr. Brown at El Paso. Mr. Jordan joined ASARCO in 1925.

MARSHALL E. PRUNTY

Marshall E. Prunty has been named district sales manager, coal preparation equipment division, Wilmot Engineering Co. He was formerly associated with Roberts & Schaefer Co. A graduate mechanical engineer of Notre Dame, Mr. Prunty will cover the coal areas of West Virginia, Kentucky, and Virginia, with headquarters in Huntington, W. Va.

Norman R. Zehr is office engineer with Ingersoll-Rand Co., New York. Mr. Zehr graduated from the Colorado School of Mines last July with an M.S. degree in mining engineering.

Frank Ebbutt, geologist, Howe Sound Co., is directing the activities of the Toronto Exploration office, Britannia Mining & Smelting Co. Mr. Ebbutt is being assisted by **Nelson Hogg,** formerly chief geologist, Snow Lake Div., Manitoba.

Frank W. Smith is now assistant technical director, American Brake Shoe Co., Mahwah, N. J. Mr. Smith was chief, Coal Carbonization Section, USBM, Pittsburgh.

Raymundo J. Chico, formerly assistant geologist, Cerro de Pasco Corp., Lima, Peru, has joined the Four Corners Uranium Corp., Gallup, N. M.

R. H. S. Ewins is mill superintendent, Cía Minera Castano Viejo, San Juan, Argentina. Mr. Ewins was with Uruwira Minerals Ltd., Mpanda, Tanganyika.

C. Richard Adelmann, Jr., mining and metallurgical engineer, California Research & Development Co., is now project engineer, University of California Radiation Laboratory, Livermore, Calif.

William H. DeHuff is district manager, Harnischfeger Corp., San Francisco. Mr. DeHuff has been with the company since 1950, and was formerly in the Chicago office.

Robert C. Mills has joined Lee Redman Equipment Co., Phoenix, Ariz. Mr. Mills was with Hewitt-Robins Inc., Los Angeles.

Edward Day Dickerman, metallurgist and field engineer, Minerals Engineering Co., Grand Junction, Colo., is now metallurgist with The Galigher Co., Monticello, Utah.

James Ivers, Jr., has been appointed coordinator for iron and alloying materials, Office of Minerals Mobilization, U. S. Bureau of Mines. Mr. Ivers was formerly with M. A. Hanna Co., Michigan, and has also done mining consulting work in Salt Lake City.

James J. Bean is chief metallurgist, Miami Copper Co., Miami, Ariz.

W. T. Bradley, assistant to the general manager, Phosphate Minerals Div., International Minerals & Chemical Corp., Chicago, is now European manager at the company's office in London, England.

C. W. Sphar has been promoted from mine engineer to superintendent, quarries and mines, Johns-Manville Products Corp., Lompoc, Calif.

Robert M. Gammell, mining engineer, Lookout Mining & Milling Co., Kellogg, Idaho, is now manager of the United Exploration Syndicate, Grand Junction, Colo.

H. R. Hendricks has joined the staff of Lewisohn Copper Corp. in Arizona, Mr. Hendricks was mill super-

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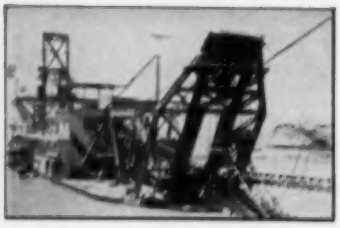

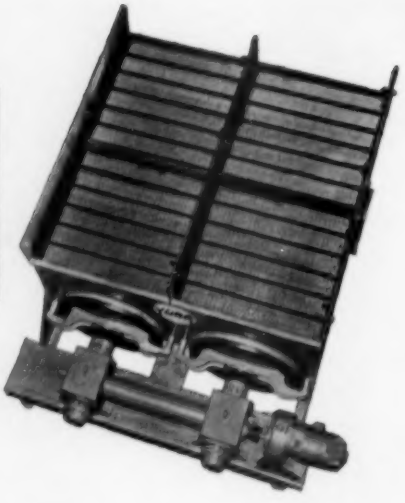

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intendent, Silver Bell Unit, American Smelting & Refining Co.

Philip S. Broadhurst is now a consulting mining engineer with the firm of Halet, Broadhurst & Ogden at 119 N. May Street, Fort William, Ont. Mr. Broadhurst was formerly mine manager, Coldstream Copper Mines Ltd., Kashabowie, Ont.

Donald Reed Stevens, Jr., has joined National-Standard Co., Niles, Mich. Mr. Stevens was with the Freebrook Corp., Kittanning, Pa.

Lewis P. Bush, mining engineer, The New Jersey Zinc Co., Platteville, Wis., is now assistant mine superintendent, The International Salt Co., Retsof, New York. Mr. Bush recently completed two years of military service as a field engineer in the U. S. Army Chemical Corps Research and Development Program.

W. R. Newman, consulting geologist, has opened a new office at 608-133 Richmond Street West, Toronto, Ont. Mr. Newman is retaining his office at 103 Mercantile Bldg., Edmonton, Alberta.

F. L. HOLDERREED

Edward R. Borcherdt has been promoted to director of mining research with headquarters in Butte, and **Francis L. Holderreed** to director of metallurgical research for the Anaconda Co. in Anaconda, both in Montana. Mr. Borcherdt, a native of Iowa, has been chief research engineer for the company since 1938. A graduate of the University of Michigan, he received his degree in mining engineering from Michigan College of Mines. Mr. Borcherdt began as an assistant geologist at Anaconda in 1920, and organized the engineering research department in 1926. Mr. Holderreed, who hails from Oklahoma, has been with the company since 1940 at which time he was a chemist, joining the research department the following year. He received an M.S. degree in metallurgy from the Montana School of Mines after graduate work at the University of Oregon.

OBITUARIES

William H. Johnson (Member 1954) died Feb. 19, 1956, in a jet plane which crashed in California. Mr. Johnson was on the engineering staff of U. S. Steel Corp. at Uniontown. At the time of his death he was fulfilling his three-year duty as an Air Force Reserve Officer. Mr. Johnson was born in Chicago in 1933. He graduated from Pennsylvania State University in 1954.

Henning E. Olund (Member 1949), retired, died in Santa Monica, Calif. Jan. 22, 1956, after a year's illness. He was born at Hudson, St. Croix County, Wis., Apr. 20, 1884. He graduated from the University of Minnesota in 1907 with a degree of Engineer of Mines. During the succeeding years he acquired wide experience and responsible positions in the mining industry as superintendent, manager, and consulting engineer. In 1926 he organized the Radior Co. of which he was vice president and director. This was one of the early geophysical companies which extended its activities to Canada, Mexico, Russia, and the U. S. In 1936 he became vice president and general manager of Darwin Mines, Darwin, Calif. He maintained an active association with this property until it was purchased by the Anaconda Co. in 1945. He then entered Government service in August 1945, as industrial specialist in the Tin, Lead & Zinc Div. of the War Production Board. In 1948 he transferred to the Mining Div., Bureau of Mines, as a mining engineer. He was later reassigned to the Minerals Div. as industrial analyst the position which he held until his retirement in April, 1954. Upon his retirement he was awarded a gold medal and a citation for commendable service with the U. S. Government.

Howard Dunbar Smith

An Appreciation by
Elliot A. P. Evans

Howard Dunbar Smith (Member 1902) died in San Francisco, Apr. 5, 1955, after a brief illness.

Mr. Smith was born in Berkeley, Calif., Mar. 22, 1881, the son of pioneer Berkeley residents, the late J. Howard and Elizabeth (Dunbar) Smith. He attended the public schools of that city and graduated from the University of California, School of Mines, in 1901.

His professional career began in the San Francisco office of the distinguished mining engineer, Louis Janin, Sr. with whom Herbert Hoover was also associated. He was subsequently a member of the firm Janin, (Louis, Sr., and Charles H.) Stebbins & Smith, afterwards, Janin & Smith. His first assignment was an examination of the well known Highland Mary at Telluride, Colo. From this period dated his long connection with Mrs. Henry C. Brown of Denver, as confidential adviser on mining matters.

Activity in Grass Valley, Calif., gold properties, Hahn's Peak, Poverty Hill, and other locations in the Mother Lode followed. The San Francisco earthquake and fire of 1906, directed his attention to rehabilitation problems growing out of that disaster. In 1909, he explored and examined gold properties in West Africa for Messrs. Taylor of London, by whom his reports were subsequently published. Until the outbreak of World War I he maintained offices in both London and San Francisco.

Mr. Smith was active in early oil developments in Shreveport and in Texas Gulf Sulphur. His major project, however, was The Consolidated Copper Mines Co. of Ely, Nev., which he developed successfully in competition with Nevada Consolidated Copper. As president of Consolidated Copper, until 1932, his office and residence were in New York City.

Development of the North Butte Copper properties in Montana, and of his own holdings in California, as well as interest in mineral exploration legislation in this country occupied his attention after he retired.

Mr. Smith resided for the past several years in San Francisco, at the Pacific Union Club of which he had long been a member. He was survived by his sister, the late, Mrs. Charles Janin of Piedmont, Calif.; a niece, Mrs. Elizabeth J. Evans of Berkeley; and two nephews, Louis D. Janin and Charles Howard Janin of San Francisco.

Carl Joseph Trauerman

An Appreciation by
J. R. Van Pelt

Carl J. Trauerman (Member 1912), for many years the secretary-manager of the Mining Assn. of Montana, died at his home in Butte on Saturday, Dec. 17, 1955, following a heart attack a week earlier. The State of Montana and the American mining industry have lost an able engineer, a highly respected citizen, and a devoted worker and leader.

Mr. Trauerman was born in Pittsburgh, on Oct. 5, 1885, the son of Mr. and Mrs. Bernard S. Trauerman. He was educated at the Pittsburgh Central High School and at the Massachusetts Institute of Technology where he studied mining and metallurgy. After two years of engineering experience in Pittsburgh, he was drawn to western mining and came to Butte in 1906 as an assayer for F. Augustus Heinze. In the next few years he followed the highly productive practice, then customary

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among young mining and metallurgical engineers, of working and gaining experience in mining and metallurgical ventures throughout the West. Trauerman's apprenticeship included periods in Montana, Idaho, Colorado, Utah, Nevada, California, Arizona, and New Mexico. In these years he was always close to the problems of the mine developer and operator, covering practically every phase of mining from the sampling of a prospect through mine development and management to the design and operation of mills and smelters. In this period he made a number of contributions to mineral technology, notably in the Rothwell-Trauerman designs for thickeners and drum filters. During World War I he was a manganese and tungsten producer and is credited with being the first to concentrate pink manganese successfully for the steel industry.

In 1920 Mr. Trauerman extended his interests to include the oil and gas business in Montana, and in 1923 he became editor of the Montana Natural Resource Bulletin, a service which provided mineral information to hundreds of newspapers and business publications. In 1926, he opened a brokerage firm in Butte and maintained his interest in this firm until 1938. Meanwhile he still had active interests in mining, and in 1935 purchased control, for himself and a group of associates, of the Ruby Gulch Mining Co.

In the mid-twenties Mr. Trauerman turned his attention more and more to problems of mining finance, management, taxation, and law. These activities soon drew him into publicity work, and he became a familiar figure and public speaker on the economic aspects of mining. Out of this background he and others saw the need for a new and active association of mining men and companies in Montana, and thus was born the present Mining Assn. of Montana. Mr. Trauerman served seven terms as its president before becoming secretary-manager, a position which he held until his death. His experience in this association made him an influential adviser on mining legislation. He appeared before many legislative and Congressional committees, and he served for many years on the resolutions committee of the American Mining Congress. He joined the AIME in 1912, and also held membership in the Northwest Mining Assn., Idaho Mining Assn., Colorado Mining Assn., Last Chance Gulch Mining Assn., Madison County Mining Assn., Beaverhead County Mining Assn., Montana Society of Engineers, and about a dozen public-service groups such as the Y.M.C.A. and the American Red Cross.

In the late 1930's and the 1940's Mr. Trauerman became associated with the Montana Bureau of Mines and Geology in Butte, supervising the Bureau's Mineral Resource Inventory of Montana. The results of this work were published by the Bureau in three volumes: a directory of Montana mining properties, published in 1940 and revised in 1949; a similar directory of the oil and gas industries, published by the Bureau in 1943; and a bibliography of Montana geology and mineral resources.

His writing was extensive. In addition to the Montana Bureau publications just mentioned, he founded the News Letter of the Mining Assn. of Montana in 1945, and for many years served as Montana correspondent of the Wall Street Journal and some 30 other papers.

In 1944 he was appointed chairman of the committee on mine

Necrology

Date Elected	Name	Date of Death
1950	Alfred Beeken	Mar. 26, 1956
1920	Charles L. Bradbury	Apr. 3, 1956
1899	Norman Carmichael	Nov. 15, 1955
1917	Martin Fishback	Unknown
1932	Victor Garate Valdez	Apr. 18, 1956
1908	Henry S. Geismer	Aug. 20, 1955
1949	Joseph C. Long	Apr. 1, 1956
1914	Laurance I. Neale	Mar. 31, 1956
1922	Heath Steele	Feb. 21, 1956
1899	Archer E. Wheeler	Mar. 8, 1956

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finance of the Western Governors' Conference, and in 1953 he became one of the original delegates to the newly-formed Western Governors' Mining Advisory Council. In November 1955 he attended the Minerals Policy Conference sponsored by the Council in Sacramento, and was instrumental in drafting certain parts of the report, especially those relating to public relations. Three weeks later, though not yet rested from the strain of the Sacramento meeting, he felt that it was important for him to attend the meetings of the Northwest Mining Assn. in Spokane. He completed his business in Spokane and returned home. But the strain began to tell, and his heart, weakened a few years earlier, suffered another attack from which he rallied temporarily, only to come finally to rest on Dec. 17, 1955. Thus ended a life which was given with single-minded devotion to the support and improvement of the basic industry of mining.

Mr. Trauerman is survived by his wife, Mrs. Frances Sullivan Trauerman, to whom he was married in Missoula, Mont., on Apr. 28, 1913; by a sister, Mrs. Nathan Rothschild of Fort Wayne, Ind.; by a niece, Miss Madeline Rothschild, also of Fort Wayne; by a nephew and niece, Mr. and Mrs. Everett Griffin of San Francisco; and by a brother-in-law and sister-in-law, Mr. and Mrs. John A. Sullivan of Oakland, Calif.

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The Institute desires to extend it privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

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Coming Events

June 16-22, Fifth World Power Conference, Vienna.

June 17-22, American Society for Testing Materials, annual meeting, Hotel Chalfonte-Haddon Hall, Atlantic City, N. J.

June 22, AIME, Columbia Section—CIM Trail and Nelson Branches, joint meeting, Spokane.

June 23, AIME, Adirondack Section, Mineville, N. Y.

June 28, AIME, Pennsylvania Anthracite Section, annual summer meeting, Split Rock Lodge, Wilkes-Barre, Pa.

July 28, AIME, Adirondack Section, lead and talc mining and milling, Gouverneur, N. Y.

Aug. 19-24, Sixth International Symposium on Combustion, Yale University, New Haven, Conn.

Aug. 23-25, National Council of State Boards of Engineering Examiners, Hotel Statler, Los Angeles.

Aug. 25, AIME, Adirondack Local Section, golf, Tupper Lake, N. Y.

Sept. 4-11, 20th International Geological Congress, Mexico City.

Sept. 15, AIME, Colorado MBD Subsection, Glenwood Springs, Colo.

Sept. 22, AIME, Adirondack Local Section, copper mining program, South Strafford, Vt.

Sept. 26-28, AIME Rocky Mountain Minerals Conference, Salt Lake City. Technical papers will represent all branches, including the Petroleum Div.

Oct. 1-4, American Mining Congress, Mining Show, Shrine Auditorium, Los Angeles.

Oct. 8-10, AIME, Institute of Metals Div., Carter Hotel, Cleveland.

Oct. 8-12, Union of Pan American Assns. of Engineers, fourth convention, Mexico City, Mexico.

Oct. 14-17, AIME, Petroleum Branch, Biltmore Hotel, Los Angeles.

Oct. 22-24, ASA, 38th annual meeting, Hotel Roosevelt, New York.

Oct. 25, 26, AIME-ASME Joint Solid Fuels Conference, *Future Role of Solid Fuels in an Expanding Economy,* Sheraton-Park Hotel, Washington, D. C.

Oct. 29-Nov. 1, Society of Exploration Geophysicists, 26th annual meeting, New Orleans.

Nov. 1-3, Geological Society of America, Minneapolis.

Nov. 3, AIME, Adirondack Local Section, football game, Syracuse, N. Y.

Nov. 8-10, AIME, Northeastern Mining Branch Conference, Hershey, Pa. Lehigh Valley Section is host.

Dec. 5-7, AIME, Electric Furnace Steel Conference, Hotel Morrison, Chicago.

Feb. 24-28, 1957, AIME Annual Meeting. Roosevelt and Jung hotels, New Orleans.

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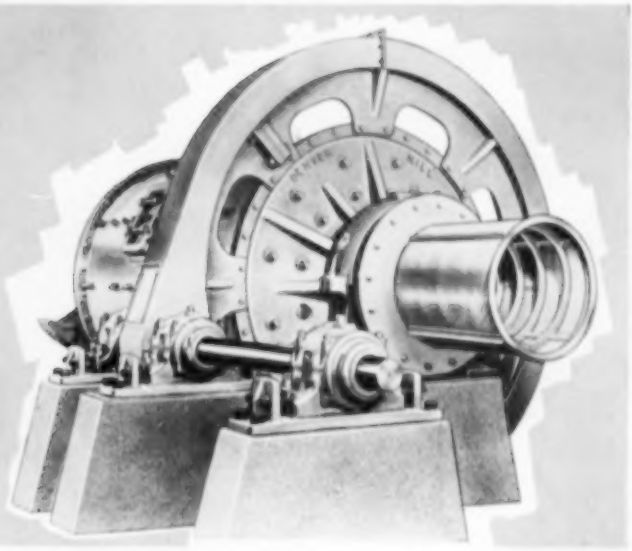

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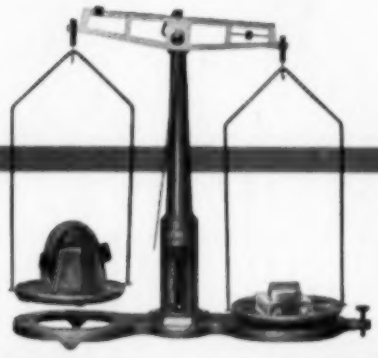

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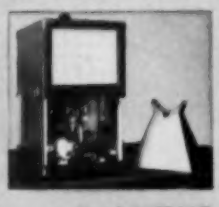

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